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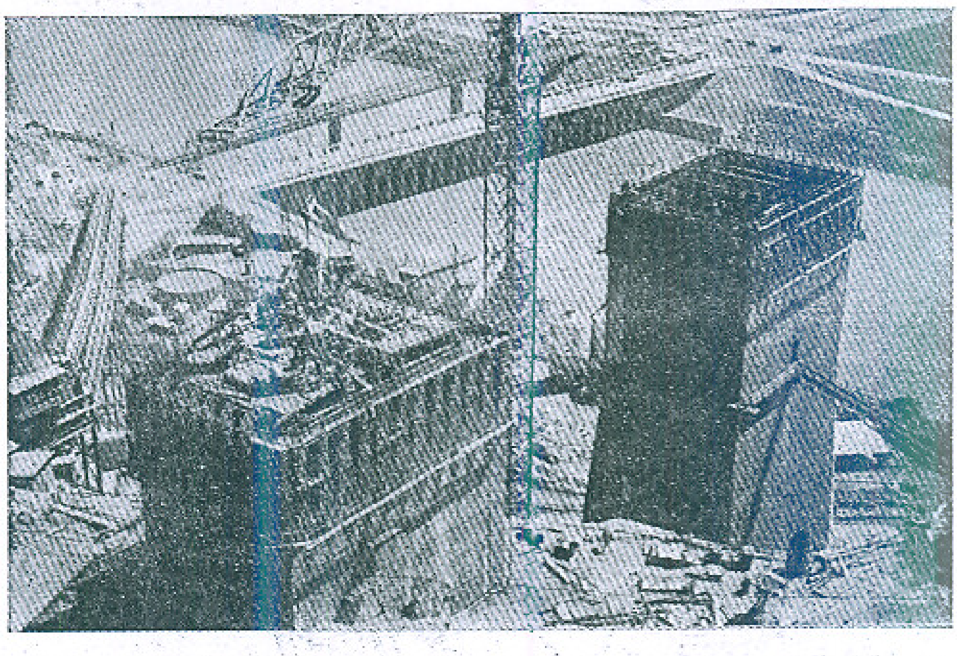
# ENGINEERING NEWS



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SEVENTEENTH YEAR OF PUBLICATION

# ENGINEERING NEWS

Quarterly Journal of the West Pakistan Engineering Congress

Vol. XVII · MARCH, 1972 No. 1

## *In this issue*

TITLE COVER

*A View of Buttress Dam and Gate Operation Structures 1 & 2 of Tarbela Dam.*


*Printed by Mirza Muhammad Sadiq at Ripon Printing Press Ltd., Bull Road, Lahore.*

# LINING OF WATERCOURSES

Water is a bounty of God. This scare natural resource is vital for agricultural based economy of our country. West Pakistan now diverts 98 m.a.f. of water from its rivers. This achievement is the result of strenuous efforts of Irrigation Engineers, extending over almost one hundred years. At present we can irrigate about 32 million acres of culturable land of the Indus Plains. Still West Pakistan possesses another 40 million acres of culturable areas for which so far no irrigation water is available. The water which is actually utilized by crops after conveyance losses is hardly 41 m.a.f. In fact about 10-20 m.a.f. (varyingly estimated by different authorities) is lost between the outlets and the fields. In watercourse alone the loss works out to be almost two to three times the capacity of Mangla Dam Reservoir. Due to shortage of water, lower delta is applied to the crops than the scientific requirements of crop and soil. To increase yield per acre, additional water is needed to meet the consumptive use of crops and leaching requirements of soil. To fill this gap, a tremendous effort is being put forth both in public and private sector to exploit the ground water.

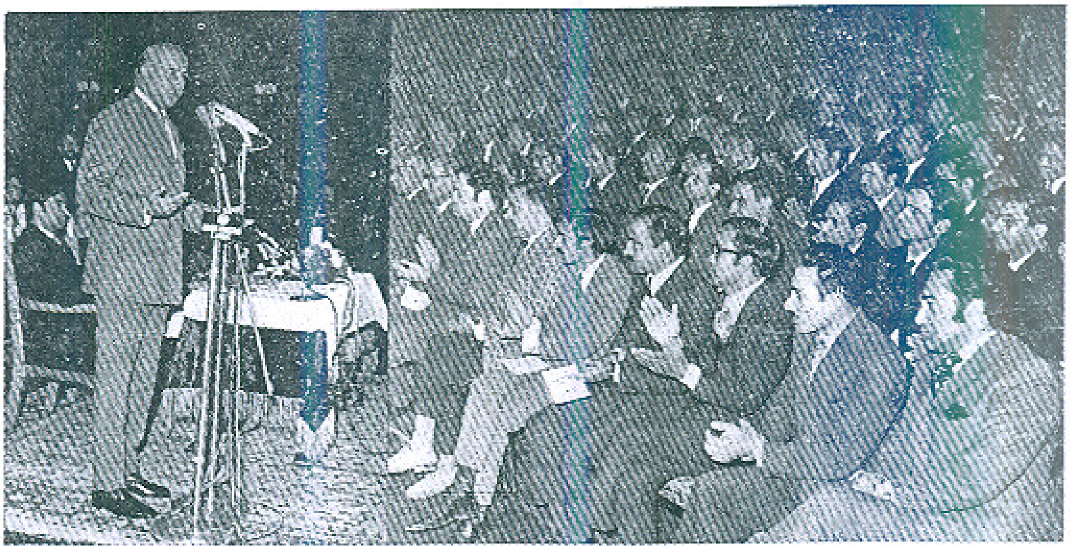
In keeping with the compulsions of a developing nation we must move with the time and the circumstances, if we have to maintain an honourable existence in the vast world of to-day. Let those who are in a position to command and to guide ponder over the subject. Time is fast approaching when another menace of deteriorated soil, intrusion of brackish water into sweet water and other problems far more acute than present waterlogging and salinity are bound to appear. If not looked at, and taken care of, in time, these problems will become far more acute.

Surface supply is a natural resource practically free from harmful elements; this cheap source of natural gift must be conserved judiciously and utilised on farms with best irrigation efficiency.

There are nearly 66,000 water courses in West Pakistan, with a total length of about 1,30,000 miles. Water losses from water courses are 10-20% and these vary with water table and soil formation. This huge loss of water, if saved even partially, can be beneficially utilized to meet the proper water requirements of crops and increase the irrigated area. The unlined water courses add 50% of their total loss to water table. This can be exploited by tubewells. And how good is the economics of their operation! The pumped out water contains salts manifold than the canal water. Thus it is a crying need of the day and advisable to line water courses. This will not only help in conserving the permanent water loss but it will help in retaining the original water quality. The achievement of this objective cannot be isolated from the overall problem of balancing the manpower needs and institutional facilities in a comprehensive manpower plan over a time horizon of at least 10 years. For the time being, it should not be impossible to entrust the bulk of planning, designing and execution to the local personnel in those areas of economy where commercially oriented concerns might disturb national priorities. The requisite operational adjustments need not be much of a problem.

All the indigenous material, with local technical know-how, is the answer to this vital problem. National resources are too scarce to be wasted just on the ground of foreign consultancy. We have to make our own contribution, if we want ourselves to be respected and if we want to avoid the degrading label of a regular hanger-on.

To realize that potential depends, on the one hand, on research to find better ways of saving and using water and, on the other hand, on embarking on an extensive program of construction of lined watercourses based on techniques that have proved in other countries with similar conditions, to be highly productive. Lining of watercourses would undoubtedly be beneficial. These need to be redesigned with more efficient cross sections, added capacity and better alignment. In most cases these should be lined with tile or plastic cloth. This type of work would be highly labour intensive, but would also require some careful supervision by engineers and sub-professional support personnel.



President Bhutto addressing Engineers at the Governor's House, Lahore.

# President Addresses the Engineers at Lahore

President Zulfiqar Ali Bhutto assured the engineers in Lahore on Sunday, Feb. 13, 1972 that he would soon launch a massive public works programme which would bring the engineers into full play and provide them with ample job opportunities.

He emphasised the need for developing a "harmonious understanding" with engineers, scientists and other talented technocrats so that they should be in the vanguard of the struggle for creating a prosperous Pakistan for which the people had offered tremendous sacrifices.

He hoped that the engineers were aware of the difficulties facing the country and would help arrive at the needed understanding without forcing issues.

Mr. Bhutto was addressing a gathering of 350 engineers in the Darbar Hall of the Governor's House at a meeting arranged by the Federation of Engineering Associations representing 14 different organisations. Among those present were the Punjab Governor Mr. Ghulam Mustafa Khar; Finance Minister Dr. Mubashar Hasan; Agriculture Minister and Provincial Advisers. An Address of Welcome on behalf of the Federation was presented by Mr. Ahmad Hasan Vice-Chancellor, University of Engineering and Technology, Lahore.

The President shared the concern expressed by Mr. Hasan on the unemployment of 2,000 engineers and assured them that they would not remain without jobs.

Mr. Bhutto said that the country's problems should be tackled in sobriety that was expected of educated persons. He wanted them to exercise a little patience. He said that for engineers and other educated people there was a method of ventilation of grievances.

If educated and responsible people devoted to creative work, resorted to 'gherao' and 'jalao' it would lead the country nowhere. He said that he understood to some extent labour resorting to such methods as they had been treated badly in the past. As a matter of deliberate policy, he said, he wanted the labour community to ventilate its grievances and allowed them six to eight weeks to let off steam because they had reasons to do so.

It was understandable in their case, he said, because their vision was limited and they had no education. But there came a time when the people themselves got fed up with it because 'gherao' and 'jalao' was "counter productive and negative." He said that the Government could not allow it to continue but it did not mean that it would become a tyrannical Government like the previous regimes.

### China's Example

He said that if the engineers also indulge in this kind of thing "then let us all wind up shop." He said that no sensible person would believe in that method. It was deprecated even in China during the great cultural Revolution. Mr. Bhutto said that when the British Legation in Peking was burnt, Premier Chou En-lai had told him that they could not permit it. Mr. Bhutto said: "When a great country like China with all its resources could not permit gherao and jalao, how could Pakistan with foreign debts and with a crisis in every sphere of its life can allow that activity?" Mr. Bhutto said that he was not threatening but was only pleading.

### WAPDA Reorganisation

Referring to the demand made on behalf of the Federation for the reorganisation of WAPDA, he said that he could not answer it in a minute. The discussion on the respective role of the generalists and the specialists had been going on for years. He said that he was prepared for a full-scale constructive debate on the matter and was willing to set up a committee to go into the question of WAPDA's problems.

Mr. Bhutto said that he had been intimately connected with WAPDA as a Minister for Natural Resources and the problems were not new to him. Nothing could be done immediately, he said, and the problems could not be resolved in a day. He said that the problem of WAPDA was associated with the sensitive question of provincial autonomy and he was not touching issues at all. He said the reorganisation of WAPDA would be determined by the National Assembly and till then its fate would be in the balance.

Mr. Bhutto said that he would like to see National Assembly in session and he would be happier on the floor of the Assembly than anywhere else. But, he added, "We have to settle some preliminary, some basic prerequisites before that is done."

### Bureaucracy

Talking of bureaucracy, he said that he did not have any particular attachment for it. Throughout his election campaign, he said, he had openly criticised its mentality. He said that on taking over office, among the first directives he had issued as one that called upon the bureaucracy to change its outlook and go to the people and get integrated with them. He said that he had told them that by sitting tight in the offices they could not hear the heartbeat of the people from the Secretariat windows.

Mr. Bhutto said that it was a pity that the bureaucracy, which was a colonial legacy, had forgotten the good things of the past and retained the bad ones. He said that the British bureaucracy attained a very high standard and in the old days the bureaucrats travelled to the remote areas where they did research work and produced valuable gazetteers. But that standard they had lost.

Mr. Bhutto said it was not merely the question of the deterioration of the standard of bureaucracy but of assertion in its privileges and powers which had created a "terrible mess." He said that like other institutions bureaucracy had not been accountable.

He said that bureaucrats had played politics and "unfortunately they played bad politics."

"If they had indulged in politics they should have at least been good politicians. But how can a bureaucrat be a good politician? This is a contradiction in terms."

Mr. Bhutto said that he wanted to do justice to everyone. The question of generalists and specialists affected all fields.

"If we set a principle in WAPDA we might have to follow it in other fields. We have seen how disastrous it was for a General to be in charge of the last war. As Supreme Commander and Commander-in-Chief, he could not give clear orders as to what should be done. "War is too serious a business for Generals," he quoted Clemenceau.

He said that there should be a happy blending and conciliation of two opposing view-points according to the requirements of the country. On the question of generalists and specialists, he said, he had an open mind and held no brief for one or the other. He said that he wanted to achieve an understanding not only with engineers but with all talented persons to stregthen the country and create a new and great Pakistan.

He said that he had great respect for engineers and he knew that they were to build the country. The engineers, he said, had to do the creative work. In the Second Five-Year Plan, 61 per cent and in the Third Five-Year Plan 63 per cent of the work was supposed to be done by the engineers. He said that he wanted engineers to feel satisfied and content and if they were satisfied and content they would build a real Pakistan.

# Address of Welcome to Mr. Zulfiqar Ali Bhutto, President of Pakistan by Engineers of Pakistan

*Presented by*
MR. AHMAD HASAN, *S.Q.A.*
*Vice-Chancellor*
*West Pakistan University of Engineering and Technology, Lahore*

Mr. President, Mr. Governor,
Honoured Guests and Brother Engineers—

On behalf of the Federation of Engineering Associations of Pakistan, on behalf of the Engineers of Pakistan, it is a great honour for me to welcome you, Mr. President, amongst us today. This is a role, a younger engineer should have rightfully played. But having been asked by them to play this role on their behalf, you find me standing here duty bound to my dear young colleagues.

Mr. President, some of us here have had the privilege of seeing you personally over a number of years. We are aware that you are for candour. And, candid we shall be. We are aware of your keen insight into the reasons for our backwardness, poverty and weakness. We are aware of your knowledge of the factors and forces responsible; and your intention of removing them, so that all the people of Pakistan, with the help of engineers, scientists, workers and other professional people, can participate in making their country strong and prosperous.

If some of the things we say are close to what you have said in your books, in your speeches and in your party's manifesto, it is because, fortunately, there is a real identity of views, for you and we have roots in this sacred soil of ours.

Today happens to be the 3rd anniversary of the Engineers' March on Shahrah-e-Quaid-e-Azam, Lahore, when thousands of engineers took out a procession protesting against the tyranny of an oppressive administrative system, following the lead provided by you, Mr. President. But while Pakistan is moving in the right direction politically, the engineering fraternity has continued to suffer from colossal neglect and inattention. Your administration has indicated a welcome change in Government thinking. We commend, for example, the setting up by you of the Ministry of Science & Technology. We hope it would be able to play an important role and that this pioneering attitude of your Government would lead to the setting up of a separate Ministry of Production.

**Neglect of Engineering and Technology**

But these measures, we hope, are the mere beginnings of a more professional attitude on national administration. This is the age of Engineering and Technology. In war, or in peace, only those nations that realise this can exist, succeed or make progress. In the West this is undoubtedly an accepted fact. America's power lies in nothing more than its excellence in engineering and in its dominance in technology. Russia owes its position of being a superpower by conceding the highest importance to her engineers.

One of the most important contributions, Chairman Mao Tse-tung made to the beginning of China's resurgence, was in massively committing, in the 1930s, his party to technology. The ascendancy of the West over the Musalmans commenced when the Musalmans abandoned science and evolved a wrong stratification of society, in which engineers were relegated to the lower levels without hope of rising to the top. Brilliant engineers of Pakistan have either left us, or have been made subservient to mediocre civil servants. The present system, therefore, ignores talent and encourages mediocrity. Even if we produced a scientist like Einstein, an engineer like Kettering or a Packard, he would have ended up heading a small department, far removed from high policy and decision-making, relegated far, far below the ordinary generalist bureaucrat.

Pakistan's powerful bureaucracy did not allow engineering and technology to come up. It usurped control of all facets of national life. It also attempted to discredit everybody else, including the politicians, the technicians, the engineers, the lawyers and the teachers. Inevitably, these Jacks of all trades have led us to our present state of affairs. While time would not permit me to catalogue all the parasitic influences that have stunted our growth, I will endeavour to highlight some of them. In this context I shall refer only to Planning, Industries, Natural Resources, the Autonomous Bodies, Production and Defence etc.

**Planning Failures**

The defects in planning were many :

— No clear goals were set, nor priorities realistically fixed, the plans mitigated against the vital concepts of economic and social justice and economic emancipation.
— Only capital-intensive investment and low productivity oriented economic planning was practised, completely ignoring our abundant resources of manpower.
— The incorrect philosophy that foreign loans were the only means of development was universally adopted.

After 24 years of independence, we are in debt to the extent of over Rs. 3000 crores, with a present annual debt servicing liability of over Rs. 100 crores, and what have we achieved? Our standard of living is still hardly above subsistence level and we are amongst the poorest in the world. We are nowhere near attaining self-reliance. Our resources remain unexplored and untapped.

Another most serious defect in policy has been the assumption that we could go in easy stages from consumer industry to intermediate industry and then on to heavy industry, instead of the other way about.

**Planning Priorities**

The most urgent need, then, is to reorder the priorities of economic development afresh.

*Self-Reliance:*—This must be based on self-reliance, on our own material, engineering and technological resources. The example of our neighbouring country, China, clearly shows that real development cannot take place with foreign loans and foreign assistance.

In reframing our future plans we have to understand and act upon a fundamental change in concept. Instead of relying on the unreliable crutch of borrowed technology, we should emphasise our indigenous techniques and resources keeping in view our peculiar socio-economic conditions. Japan and China, two countries which have achieved unprecedented technological growth, are good examples in point.

*Education.*—Increasing knowledge is a key factor in a country's international economic strength; so we must educate our people extensively in engineering and technology. The present Government appears to be fully cognizant of this aspect and we anxiously await the massive educational drive which, we hope, will have the necessary technological bias.

*Technology in Agriculture.*—The backbone of our agricultural economy must be strengthened and its productivity very substantially increased by the application of labour intensive techniques which can be developed locally. This would also go a long way in solving the rural unemployment problems.

**Steel Mill and Engineering Industries**

There is absolutely no justification for not having a steel mill till today. In 24 years, we imported steel and steel products worth Rs. 4000 crores in foreign exchange out of our own cash resources but did not invest Rs. 200 crores to set up a steel mill earlier. Indigenous raw materials and processes have not been fully exploited. Steel is basic engineering material and could have given us a starting point to make machinery, vehicles, engines, tanks, guns and much else. We must go in for these industries as they alone generate the process of capitalising our labour and the country has the required expertise amongst its engineers and technologists to accomplish this task.

**Mineral Resources Exploitation**

With better and more serious efforts on the exploration and exploitation of the mineral rescources available in West Pakistan, we could have had many metals that were quite. Again, because of the unscientific and non-technical approach, this source of wealth and strength was not given due importance.

**Autonomous Bodies**

The record of the autonomous bodies has also not been very happy. Not one of them realised its true potential, because they have been headed by generalist civil servants and retired generals who had neither the required professional knowledge nor the administrative ability to manage such involved engineering organisations. The engineers, in turn, remained frustrated because they were not allowed to work properly or contribute their best. The engineers have made detailed analysis of the functioning of these bodies and have submitted proposals for revitalising them.

Had there been a proper and appropriate understanding of the engineering concepts, WPIDC should have given a lead in machinery producing industry. WAPDA is another sad story. With 2500 engineers, it is the largest engineering organization in the country. Yet it has been controlled and headed by bureaucrats, ignorant, we believe, of the problems of such a large and complex organization, let alone having the ability to solve them.

WAPDA has a vital role in our agricultural and industrial sectors. It had spent over Rs. 1750 crores up to June, 1971. Its annual expenditure is more than half the development expenditure of the West Pakistan provinces. It can be a great force for development if properly organized and headed. Its efficient running is, therefore, of basic importance for the co-ordinated economic development of West Pakistan.

WAPDA's mismanagement has remained a cause of immense concern for its engineers for long. All their concerted efforts at getting the management to take the right steps to improve the organization have been persistently ignored, as have been the studies and proposals for its improvement by the World Bank, the U.S. A.I.D., as well as the Government Study Groups. Even Lord Hinton, former Head of the British Electricity Authority and a World Bank Consultant, has strongly stressed the necessity of dropping the civil service pattern and praised WAPDA's younger engineers.

And this, Mr. President, is the background of the struggle of Wapda Engineers, recently highlighted in the press.

Their struggle is solely in the national interest. And that is why they have appealed to your Government to change the WAPDA management and its administrative system. WAPDA's engineers have a deep knowledge of the serious shortcomings of the organisation and believe that WAPDA can render immense services to Pakistan and its people if, and I repeat if, properly run. They realise too well the grave consequences of continuing with the status quo and the serious harm that would be caused to the national interest if the urgency of the situation is not realised. These engineers have also prepared for the Government detailed studies and proposals in this connection.

While talking of over-due management reforms in WAPDA, I would like to take this opportunity of mentioning a few instances where, because of non-professional leadership, serious mistakes were made resulting in huge national losses. The design of Tarbela Dam is perhaps the most scandalous episode. A serious defect in its design was pointed out as early as 1966. The WAPDA Administration run by CSP's could not appreciate it and the engineers have been struggling for a 5th tunnel at Tarbela ever since. The Tarbela Dam is expected to be commissioned in 1974 and if the additional tunnel is not completed by then, there would be water famine in the Kharif sowing season. It would indeed be a great tragedy that after constructing a gigantic dam the size of Tarbela, the areas in Sind, Punjab, Baluchistan and Dera Ismail Khan should be deprived of the natural flows of the river Indus in the Kharif sowing season. What will happen is that the rising flows of the river in the months of May and June instead of rushing down to the millions of irrigators waiting anxiously for it, will start to pond up until the spillway comes into operation after ponding up 6.5 MAF. But, unfortunately, by that time the sowing season for cotton and rice will have passed. This is only one example of what it has cost the country to have non-engineers control the policies in WAPDA.

There are other legion instances where the non-technical WAPDA Administration, leaning heavily on the advice of the foreign consultants, was responsible for serious loss to the country. In the case of design of a Link canal, the WAPDA Administration supported the foreign consultants against the advice of the Pakistani Engineers and cotroversy dragged on for nearly a year and cost WAPDA over Rs. 50 lacs; but ultimately the Pakistani Engineers' view-point was accepted. The cost of the Link as proposed by the Pakistani Engineers further resulted in a saving of as much as Rs. 6 crores.

In another case, the foreign consultants were able to influence the non-technical Administration of WAPDA to accept a project costing nearly Rs. 7 crores for the Gaja area. This was strongly opposed on technical reasons by the Pakistani Engineers and the matter had ultimately to be resolved at the highest level. After listening to the arguments of the Pakistani Engineers and WAPDA, Administration, ex-President Ayub Khan gave his decision in favour of the Pakistani Engineers, thus resulting in a saving of Rs. 7 crores.

Still another example to be quoted is where the WAPDA Administration employed foreign consultants who had come up with a recommendation to abandon 42 lakh acres of irrigation area in Sind out of a total of 132 lac acres. This was strongly objected to by the Pakistani Engineers and the proposals prepared by the foreign consultants, readily accepted as the gospel truth by the WAPDA Administration, had to be discarded. WAPDA had to pay a large amount of money to the Consultants to prepare these proposals. Such things could not have happened if WAPDA's Administration was controlled by technical people. Similar examples of how bureaucratic non-technical leadership in organizations like WAPDA resulted in great national loss can be multiplied. But I have chosen to speak only of the few important examples in which I was personally involved.

The recurrent power shortages, if investigated, may well point to similar crises in non-professional leadership coupled with unquestioning deference to foreign consultants.

### Productivity

Mr. President, we are aware of your concern for increasing productivity. That our productivity is low, is well known. It goes without saying that we could achieve optimum productivity, earn and save foreign exchange only by letting the professional engineers give the lead in national economic activity, as is the normal practice in all developed countries. To achieve the goals of maximum productivity, the engineers have suggested the setting up of National and Provincial Productivity Councils composed of engineers.

### Defence Production

The neglect of engineering industries capable of producing armaments is a very serious national handicap. Here, again, failure of the previous regimes to have effective organizations headed by competent engineers, instead of retired non-professional officers, is the reason. No time can be lost on this front; and the Pakistani engineers, given their rightful role, would not be found wanting.

### Unemployment of Engineers

In the context of general unemployment in the country, one engineer employed creates jobs for 100 persons. There are so many horizons and so many vistas in which the engineers can contribute in this respect

There can never be adequate engineers in a developing country. Engineers are a nation's wealth. We are not developing sufficiently or rapidly enough; yet we have over 2000 engineers who are unemployed today. Conditions obviously exist that prevent engineers in the right numbers and in the right positions, from serving the nation. This applies to both, the public and private sectors. Engineers have been repeatedly bringing before the previous Governments definite solutions but have not been able to get responsive action. Hopefully, this will be forthcoming now.

In the private sector, the current reduction of development activity in the country threatens the future of the several excellent Pakistani consulting engineering firms that had come up in the country. These firms had begun to aggressively compete in local and foreign markets. Every effort should be made to utilise their services in the national development so as to progressively replace the foreign consultants.

**Engineering Council**

We are not unmindful of the fact that, like other sectors, some of the engineers may have been swayed by the general unethical national climate. They are a part of the "system". But we are determined to clean our house. In this connection we have proposed to the Government the establishment of the Engineering Council of Pakistan which, in addition to its other responsibilities, is intended to eliminate malpractices and to regulate the conduct and ethics of its members. We hope this will receive prompt attention. The engineers are the only profession seeking voluntarily this self-corrective action.

**Administrative Reforms**

Mr. President, we could not agree more with you that the challenges Pakistan faces today and the tasks ahead are gigantic and complex.

While we are confident that Allah has gifted you to tackle the political field efficiently, we believe that the battle of reconstruction of the shattered economy of the country can be tackled only with the active participation of the engineers and technologists whom we all assembled here today represent. Permit me, Sir, to make an honest admission. During the 42 years of my association with this profession, never have I found that the engineers given a task, no matter how difficult, did not rise to the occasion to accomplish it in time. Having been faced with a challenger, they devotedly set to work and accomplished their tasks in the service of the nation. This has been in spite of the fact that the bureaucratic administration seldom acknowledged their efforts in an appropriate manner. The engineers worked and toiled and the laurels and titles mostly went to the C.S.P.'s.

You, Mr. President, have rightly declared in clear terms that you want a liberal and dynamic bureaucracy, "not based on the old British colonial pattern". Your party's manifesto has committed that administrative reforms are an urgent matter. That is why we are confident that your Government will not have the misconception that the previous regimes have had; and this misconception was that only one particular service should monopolise all the decision-making positions. In your own illustrious career you have met the leaders of many countries, some of them undoubtedly must have been engineers. We are very happy to note that in the Cabinet you have given an important portfolio to an engineer member of your party.

I feel we need not stress any longer that, to carry out your programs, particularly the massive public works programs, that you are sure to embark upon, your Government urgently needs a drastically reformed administrative machinery. We are, therefore, confident, that the services will now at last be professionalised. The integration of services with the engineers forming the back-bone, with no particular service being able to lay claims on all the senior positions and the engineers not suffering because of the present seniority system, is required. Appointments should then be possible on technical competence, talent and ability, and on job requirements, rather than the exclusively of one service. Only if positions in Government concerning engineering, technology and development are manned, at all levels, including the highest, by engineers, can the nation expect to move forward. In a memorandum already submitted by us to the Government, we have indicated the positions that should rightly be manned by engineers.

Mr. President, we have had opportunities to greet Presidents and Governors in our midst before. But during those occasions we mostly heard from them their speech writers' CSP voice. Today, we are confident to hear differently. We hope we shall have occasion to directly communicate with you often and in this connection we would request the appointment of engineers in your personal staff as well as advisers on Engineering, Technology and Development.

Mr. President, as I said earlier, all we ask for is the right to serve our country effectively. We urge you to appreciate that we wish to serve. The country cannot afford not to utilise its engineers, and we do not want our future generations to condemn us for being indifferent at this critical juncture of our national existence.

PAKISTAN PAINDABAD

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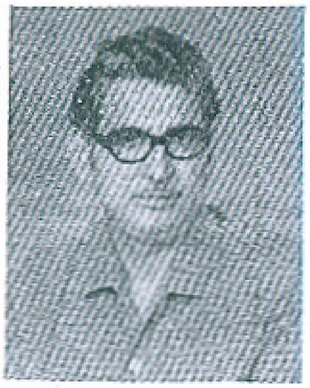
# Irrigation and Power Section



# Taunsa-Panjnad Link Canal Unlined versus Lined Channel

*By* SYED NAZAR HUSSAIN MASHHADI
B.Sc. Engg. (Mech) B.Sc. Engg. (Civil),
Executive Engineer (*Retd.*).

*Taunsa-Panjnad Link has been constructed as an unlined canal after thoroughly comparing the merits and demerits of an unlined channel with that of a lined one. However, running of the link with higher discharges resulted in heavy waterlogging in the areas adjacent to the link and damage to the public utilities therein. This naturally reopened a controversy and started intriguing the mind of every common engineer as to why the link could not be lined to obviate the catastrophe resulting after peak operation of the link. Here in this article the author (who has worked on the Design, Construction, Contract, Administration and Maintenance of Taunsa-Panjnad Link for over eight years) has tried to enlighten the readers about the original design concept in the years 1965-66 before construction of the link. However, actual behaviour of the link during operation and after-effects of peak operation, in the years 1970-71, such as waterlogging, effect on the acquifer and damages to public utilities will be followed in the second instalment of this article.*

**General**

One of the original proposals for the Taunsa-Panjnad Link that were considered by the Indus Basin Advisory Board (I.B.A.B.) contemplated that the last 26 miles of the Link, where the sub-soil water-level was deep, would be lined in order to reduce conveyance losses. From a study made by M/s Tipton and Kalmbach in February 1961 entitled "Lining of Link Canals", it was concluded that lining of the Taunsa-Panjnad Link could not be justified because of the following factors :—

(*a*) Water tables are relatively high in the area traversed by this link and while presently lying up to 10 to 12 feet below the bed level of an unlined link would only be a few feet below the bed level of a lined link.

(*b*) Much of the area lying under the irrigation systems served by the canals taking off from the left bank of Taunsa Barrage is waterlogged or is in danger of being waterlogged.

Reclamation of this area is presently required and tubewells, provided in lieu of lining, will fit in well with such a scheme.

(c) Groundwater in this area is of marginal quality and leakage of good quality water from a link canal will be beneficial to any reclamation schemes in this area.

(d) An unlined link together with the equivalent of 445 tubewells can be provided to give service equivalent to that of a lined link at a saving in cost equivalent to 12.5 million rupees.

(e) Excess slope is available for this link and it may be possible to devise whereby part of its excavation can be accomplished through retrogression by the flowing water with a consequent saving in cost. Such a scheme could not be utilized if the link were to be lined.

The feasibility of providing lining has again been examined with the more refined and authentic data presently available. To appraise this problem, it is necessary to consider not only the cost of the lining and the reduction in losses that might be effected thereby but also the effect of leakage from the link on the aquifer and the utilization of water stored therein as a source of future Tubewell Irrigation.

As shown on the profile given in Figure 1 the link has been divided into the following main reaches :—

(i) R.D. 0+000 to 59+600 (head reach)

(ii) R.D. 59+600 to 131+300 (middle reach)

(iii) R.D. 131+300 to 183+000 (tail reach)

(iv) R.D. 183+000 to river chenab. (outfall channel).

The only reach of the link in which lining could feasibly be constructed and maintained is between R.D. 131+300 and the outfall at R.D. 183+000, a distance of 10 canal miles. In this reach the sub-soil water-level is presently at varying depths up to a maximum of about 12 feet below the bed level of an unlined link and 6 feet below the bed of a lined link.

In the reach R.D. 59+600 to R.D. 131+300 the present sub-soil water-level, although sufficiently below the bed of an unlined channel is almost above the bed of a lined channel and not only would costly measures be required to dewater areas in this reach to permit construction of lining but also the link would have to be operated in such a way as to continuously maintain a positive head of water on the lining. Another measure to safeguard the lining in this reach could be to construct humps in the bed of the channel at regular intervals to retain certain depths of water commensurate with the uplift pressure due to sub-soil water-level prevailing or expected at those locations, but this will also involve extra expenditure.

However, for the sake of comparison between the cost of lining and the revenues accrued from the seepage waters saved, it is assumed that lining in the reach R.D. 59+600 to R.D. 183+000 (24.7 canal miles) is technically feasible.

In the remaining reaches of the link it would be technically infeasible to attempt to line the canal section because of high sub-soil water-levels due to which any lining would be subjected to external pressures when the link is unwatered even under present conditions. These pressures will inevitably increase with the rise in ground water tables with consequent destruction of the lining that might be provided.

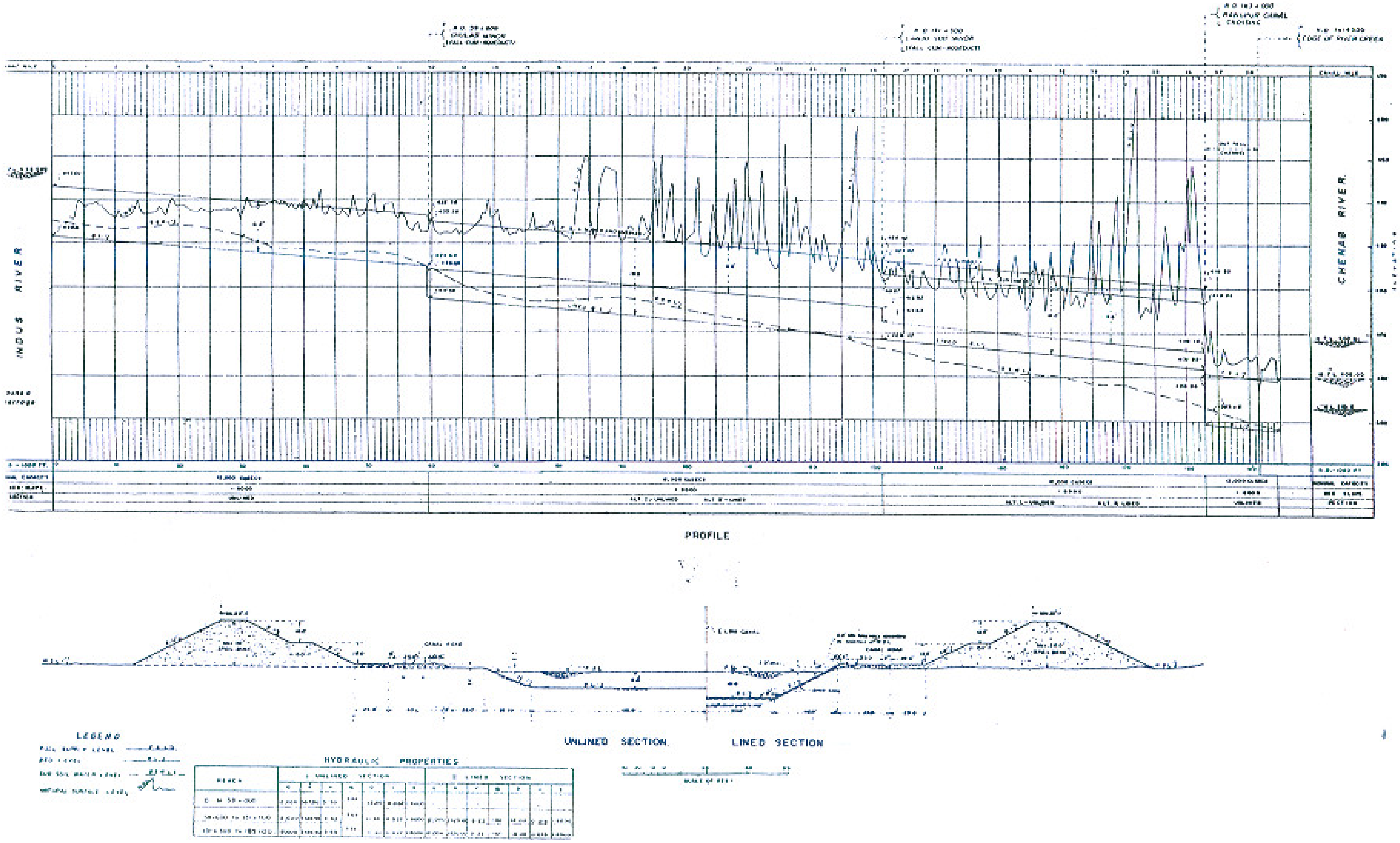



Figure 1. Taunsa-Panjnad Link Canal Unlined versus Lined Channel Profile and Sections.

## Seepage Losses

By referring to the profile of the link shown on Figure 1 and the computations given in Appendix-C, it may be seen that the seepage losses in the reach from R.D. 59+600 to R.D. 183+000 may be in the order of 486 cusecs. There are very little reliable data on seepage loss rates from lined canals, but a value of two cusecs per million square feet of the wetted perimeter is commonly used for brick lining in West Pakistan. It is believed, however, that this rate is much less than what would be obtained by lining a large channel as Taunsa-Panjnad Link passing through an arid tract of Lower Thal Doab.

A lined channel for the Taunsa-Panjnad Link operating on 1 : 8000 slope would have a base width of 100 feet, full supply depth of about 18 feet, and wetted perimeter of 181 feet, or about 55 per cent of that of the comparable unlined channel (see Appendix-B). If it were possible to reduce the loss rate to two cusecs per million square feet, by lining, seepage losses would be in the order of 1.80 cusecs per canal mile or about eleven per cent of the seepage losses from an unlined link. If, therefore, the 24.7 miles reach were to be lined, it might be possible to reduce conveyance losses by a maximum of about 441 cusecs when the link is flowing at full supply depth (Appendix C).

## Cost of Lining

To line the 24.7 canal miles reach of Taunsa-Panjnad Link would be much costly because of the virtual absence of suitable clay formations for the manufacture of tiles which would necessitate their being hauled from brick kilns situated at considerable distance from the Link. Moreover, the sub-soil waters under the areas traversed by the link are mostly brackish (containing 1000-2000 p.p.m. dissolved salts) and the clayey soils sparsely located between the sand dunes are impregnated with salts which render the tiles manufactured from such soils almost useless for the purposes of lining. It is believed that good quality clay is available on the right side of Indus in D.G. Khan Ditst. and if the brick kilns are located on that side, extra haulage involved may be in the order of 30 miles with the resulting increase in cost. While no extensive investigations have been carried out to locate the closest sources of suitable clay, it is conservatively estimated that brick masonry lining with an asphalt memberance would cost at least Rs. 250.00 per 100 square feet (the corresponding rate of the lowest tender for lining on the Sidhnai-Mailsi Link is 180 rupees per 100 square feet).

Appendix A shows a comparison of the estimated cost of construction of an unlined and a lined canal for the 24.7 miles reach of the link under consideration. It may be noted that a lined canal would cost more than one and a half that of an unlined canal, the incremental cost of lining being about 42 million rupees or 1.7 million rupees per canal mile as shown in Appendix C. Assuming it were possible to reduce seepage losses from 19.7 cusecs to 1.80 cusecs, per canal mile by lining, the capital cost thereof would be equivalent to about 95,000 rupees per cusec reduction in seepage loss.

In order to appraise the justification of lining, it is necessary to compare the foregoing construction cost with the value of the water that would be saved by lining. While there would be some losses incurred in conveying water from tail of the link to points of potential use downstream, it can be assumed that the losses on the increment of flow that would be saved by lining the link would be small and that one cusec reduction in seepage loss from the link would be equivalent to a cusec delivered at an outlet of a downstream system.. From the stand-point of revenue to the Irrigation Department, one cusec of water at the outlet has a value of about 2000 rupees. If this amount is capitalized at four per cent interest, it is equivalent to 50,000 rupees per cusec. This amount can be considered as representing what the cultivators can afford to pay for water under present conditions. It could be argued that when used under an existing developed irrigation system, a saving in seepage losses from the link represents a supply supplemental to the basic canal supplies and hence has a higher value. Such a value, however, would have to be more than twice that of the existing supplies in order to justify the cost of lining.

**Recovery of Losses**

While this simple comparison of cost of lining and the revenue that would be derived thereby indicates that lining is not justified there are certain other aspects which reinforce this conclusion. Among these is the fact that seepage losses from the unlined link do not represent a permanent loss of water and, in fact, can create, through their storage in the aquifer, a source of supplemental supplies of great potential value for the future Tube-well Irrigation, Salinity Control and Reclamation Schemes in the Lower Thal Doab. These aspects can be more readily understood by referring to the data portrayed on Figure 2 which shows groundwater table contours in the southern (lower) portion of the Thal Doab as they existed in 1935, plotted dotted. The groundwater table contours as they existed in 1960-62 are shown in firm lines. These contours (which generally depict the present position of the water table) take into account the rise in water table which has taken place since the commissioning of weir-controlled non-perennial Rangpur Canal system in 1939, the perennial Thal Project in 1947 and conversion of Darajat inundation canals into weir-controlled non-perennial Muzaffargarh Canal system in 1959.

The geological characteristics of the alluvium and existence of a bed-rock underneath plays the most important part in controlling the equilibrium of the groundwater table. Whereas the total thickness of the alluvium in the Lower Thal Doab is not known but deepest test holes (up to 900 ft. depth) drilled in the area by WASID of WAPDA and other geological considerations indicate that there is no significant change in the character of material with depth, the thickness of the alluvium may be several thousands of feet and no bed-rock has been encountered during the drilling operations.

The alluvium is saturated with water to within a few feet to the natural land surface. Since there are no extensive beds of impermeable nature the groundwater is generally unconfined and because of the narrow width of the doab between the two rivers, the depth to water probably never has been more than about 30 feet below ground surface in any part of the area. A perusal of Figure 2 indicates that in the past 25 years, except in a few places, there has been no pronounced change of water table level such as that observed in other parts of the Punjab. It is, therefore, probable that the high water table is due to the closeness of two large rivers flanking the Lower Thal Doab area.

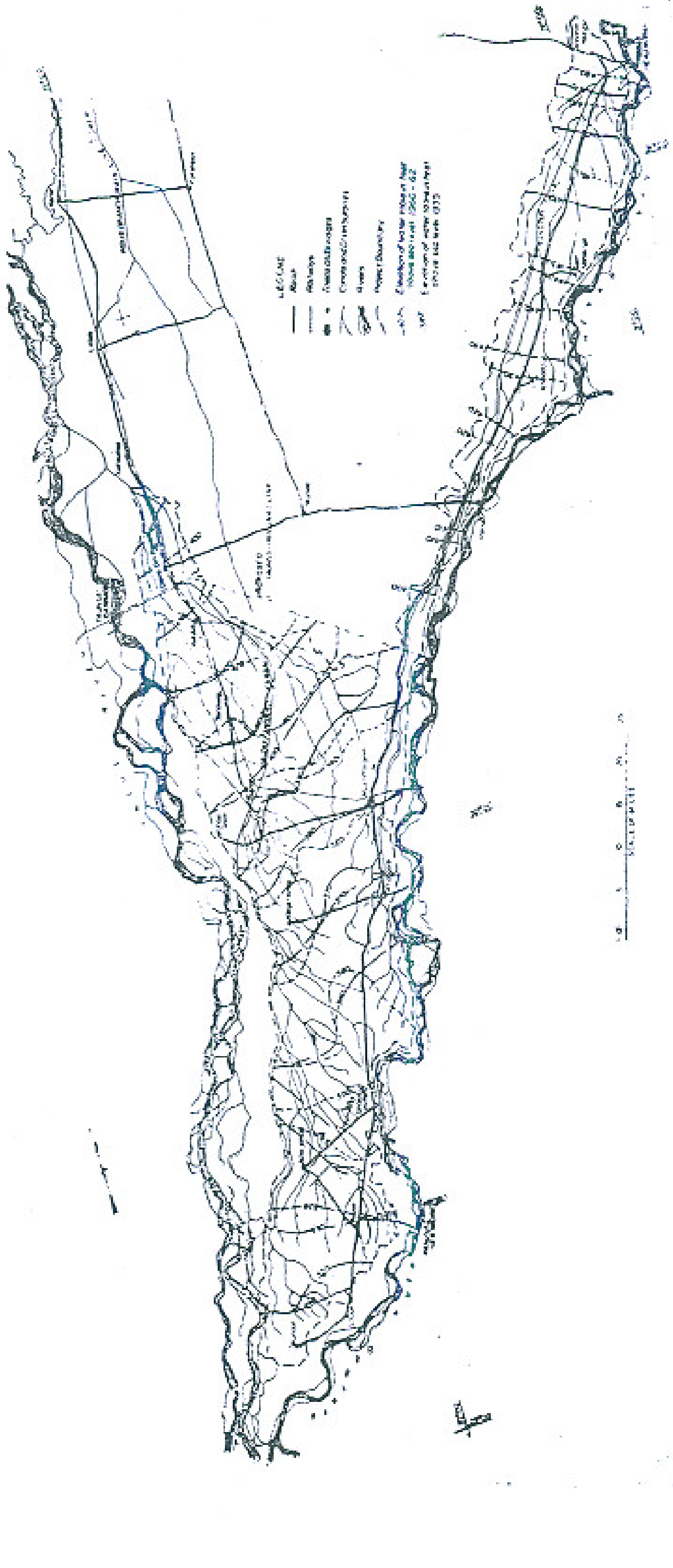


Fig. 2 Taunsa-Panjnad Link Lower Thal Doab, Water Table Elevations, 1935 & 1960-62 Averages.

Irrigation agriculture by means of inundation canals was practised in the Lower Thal Doab prior to the 19th century. These canals operated only for a few months of the year, but apparently carried enough water so that substantial quantities leaked to the water table. This leakage raised the water table to such levels that ground water outflow, including evapotranspiration, balanced the recharge from irrigation. The rise in water table was only a few feet, since at these relatively shallow depths a few feet of rise brings about a very marked increase in evapotranspiration.

The configuration of the water table shown in Figure 2 is the result of the balance of all factors of recharge and dicharge affecting the ground water. The contours of water table show the effect of a general southeasterly flow across the area from the Indus River toward the Chenab River, as well as a slight ground water ridge through the middle of the area which appears to have been caused by seepage from the inundation canals. In 1935 the ground water in the area was essentially in a state of equilibrium, with the discharge balancing the recharge. The discharge into the Chenab River probably was at least balanced by the inflow from the Indus River and the recharge from the irrigation system practically all discharged by evapotranspiration from the water table.

When the Taunsa-Panjnad Link is constructed, the configuration of the groundwater table will be modified as a result of the link functioning as a drainage channel in its upper reach and as a source of recharge in its lower reaches.

The topography of Thal Doab differs from that of other doabs of the Northern Zone in a manner which has a bearing on the disposition of outflow from the aquifer. Along the peripheries of most of the other doabs the bordering rivers are rather shallowly entrenched and the overall gradient of the groundwater table is generally in a down-doab direction towards the confluence of the rivers. As the groundwater table rose in those doabs there was very little increase in the gradient of ground-water flow towards the river and, although regeneration undoubtedly increased a small amount, most of the recharge causing the water table to rise was transpired and evaporated from the shallow water table as the lands became waterlogged. The Thal Doab is situated at such a level that there exists a pronounced escarpment, 25 ft. to 40 ft. in height along its southern border close to the right bank of Jhelum and Chenab Rivers. While the general slope and direction of groundwater flow with the Taunsa-Panjnad Link in operation will remain in southeasterly direction towards the Chenab River, any rise in the water table will result in fairly steep groundwater slopes in the same direction. Leakage from the river to the central portion of the Doab as taking place at the present will be reduced and a large portion of the seepage losses from the link after the groundwater has become stabilized will accrue to the Chenab River as regeneration. The evapotranspiration losses from the aquifer will be much less than in similar situations in other areas of the Northern Zone because the water table will stabilize at much deeper depths below the land surface. Immediately adjacent to the link where the water-table will coincide with the water level in the link when the aquifer is fully saturated, non-beneficial losses will be minimized by virtue of high spoil banks extending to significant distances on either side of the link.

If the link were to be lined, and seepage losses were reduced to the value assumed for lined canals in this study, the opportunity of making optimum use of irrigation supplies that might be carried in the link would be greatly jeopardized. This is because flow in the link for replacement purposes cannot follow a consistent pattern from period to period and year to year. As a result, no firm irrigation development could be sustained solely by using supplies conveyed in the link during periods when its capacity is not required for replacement purposes. By exploiting the groundwater aquifer, however, which, in turn, can be continually replenished by leakage from the unlined link, it is anticipated that several hundreds of thousands of acres of land in the Lower Thal Doáb could be brought under irrigation or reclaimed very economically without conflicting with the replacement function of the link. It is, therefore, concluded that lining of the Taunsa Panjnad Link cannot be justified.

## APPENDIX-A

### TABLE I

*Characteristics and Costs of Unlined and Lined Channels (Costs in Rupees)*

"A" — Estimated Construction Cost of Link— R. D. 59+600 to R. D. 183+000 (24.7 Canal Miles)

| Item No. | Description | Unit | Unit Rate | UNLINED CHANNEL Quantity | UNLINED CHANNEL Cost | LINED CHANNEL Quantity | LINED CHANNEL Cost | Incremental cost of Lining. |
|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| 1. | Excavation | cu. yd. | 1.50 | 22,200,000 | 33,300,000 | 15,000,000 | 22,500,000 | (—)10,800,000 |
| 2. | Compacted Embankment | cu. yd. | 1.00 | 674,000 | 674,000 | 1,348,000 | 1,348,000 | (+) 674,000 |
| 3. | Brick Lining | 100 s. f. | 250.00 | 0 | 0 | 246,800 | 62,700,000 | (+)62,700,000 |
| 4. | Structures | Lump Sum | | — | 28,026,000 | — | 18,684,000 | (—) 9,342,000 |
| 5. | Land | Acres | 2,000 | 2,300 | 4,600,000 | 1,700 | 3,400,000 | (—) 1,200,000 |
| | | | | Totals : | 66,600,000 | | 108,632,000 | (+)42,032,000 |

"B" — Characteristics of Waterway Sections

| Perimeter | Unit | Unlined Channel | Lined Channel |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| Bed Width | ft. | 266 | 100 |
| F. S. Depth | ft. | 11.8 | 18 |
| Waterway Area | ft./sec | 3486.9 | 2420 |
| Velocity (Q=12000) | ft/sec | 3.63 | 5.2 |
| Wetted Perimeter | ft. | 329.54 | 181 |
| Wetted Area | msf./mile | 1.585 | 0.905 |
| Seepage Loss Rate | cs/msf | 12* | 2* |
| Seepage Losses | cs/mile | 19.7 | 1.80 |

*Estimated rates of loss when subsoil water level is sufficiently far below the bed of channel as not to affect seepage gradient.

## APPENDIX-B

## TAUNSA-PANJNAD LINK CANAL

### Lining of the Channel Section

**Design Data**

Given : (*i*) Q=12000 cs

(*ii*) N=0.018 (assumed Mannings Coefficient).

(*iii*) S/Slope=2 : 1 (on the basis of S—M Link).

(*iv*) Bed Slope=1 : 8000=0.000125

Required : B & D of the Lined Channel.

Assume : $\frac{D}{B}=0.16$

By trial and error method if we assume :—

$D=16.0$ ft. then $B=\frac{D}{0.16}=\frac{16}{16}\times 100$

$=100.0$ft.

$A=\frac{100+164}{2}\times 16$

$=132\times 16=2{,}112$ sft.

$P=2\times 35.77+100=71.5+100=171.5$ ft.

$R=\frac{A}{P}=\frac{2112}{171.5}=12.3$ ft.

$V=\frac{1.49}{0.018}\times(12.3)^{\frac{2}{3}}\times(0.000125)^{\frac{1}{2}}$

$=\frac{1.49}{18}\times 1000\times 5.03\times(1.25)^{\frac{1}{2}}$

$=4.65$ft/sec.

$Q=A+V=2112\times 4.65=9{,}800$ cs,

Too Low and hence try again.

—.—.—.—

Assume $\frac{D}{B}=0.18$, D=18ft. & ∴ B=100ft.

Then $A=\frac{100+172}{2}\times 18=\frac{272}{2}\times 18$

$=136\times 18=2{,}420$ sft.

$P=(2+40.3)+100$

$=180.6$ ft.

Say=181 ft.

$R=\frac{A}{P}$

$=\frac{2420}{180.6}$ 13.4ft.

$V=\frac{1.49}{0.018}\times(13.4)^{\frac{2}{3}}\times(0.000125)^{\frac{1}{2}}$

$=\frac{1.49}{18}\times 1000\times 5.64\times\frac{11.2}{1000}$

$=5.22$ ft/sec.

$Q=A\times V=2420\times 522=12{,}600$ cs ∴ O.K

∴ Hydraulic properties of a lined channel are :

Bed width=100 ft. Depth=18.0 ft.

Side slope=2 : 1 N=0.018

Velocity =5.22 ft./sec S=1 : 8000

Perimeter of Lining up to water surface=180.6 ft.

Perimeter of lining after allowing for . .

4 ft. free board ad 2.0 ft. length to be embedded under the dowel =200 ft.

∴ Total area of lining along. . . . 123,400 ft. length of lined reach. =123,400 × 200=24,80,000 Sft.

## APPENDIX-C

## TAUNSA-PANJNAD LINK CANAL

### Lining of the Link (Saving in Water)

Computations to arrive at probable saving in water effected by virtue of lining the Link in the reach R.D. 59+600 to 183+000.

(*i*) Design Discharge of Link=12,000 cs.

(*ii*) Length of reach R.D. 59+600 to R.D. 183..000=123,400 ft.

(*iii*) Dimensions of an unlined channel as finally adopted for construction are as given below :—

Bed width B=266.0 Ft.

F. S. Depth D=11.80 ft.

Wetted Perimeter P=329.54 ft.

(*iv*) Anticipated absorbtion losses in the unlined Link at the rate of 12 cs/million sft. of wetted area in the reach R.D. 59+600 to 183+000

$$= \frac{123,400 \times 329.54}{(10)^6} = 486 \text{ cs.}$$

(*v*) Dimensions of an equivalent lined channel from Appendix-B for the same reach area :—

Bed width B= 100 ft.
F. S. Depth D= 18.0 ft.
Wetted Perimeter P= 181.0 ft.

(*vi*) Absorption Losses in the lined reach at 2 cs per million sft of wetted area

$= 123,400 \times 181 \times 2 \times (10)^{-6}$
$= 44.7$ cs
Say $= 45$ vs.

(*vii*) Probable saving in water effected by lining 123,400 ft. or 24.7 canal miles length of link=(iv)—(vi)=441 cs.

(*viii*) Seepage loss rate of an unlined channel
$= 486 \div 24.7$
$= 19.7$ cs/canal mile.

(*ix*) Seepage loss rate of a lined channel
$= 44.7 \div 24.7$
$= 1.80$ cs/canal mile.

(*x*) From Appendix-A the incremental cost of lining 24.7 canal miles reach of Link =Rs. 42,032, 000

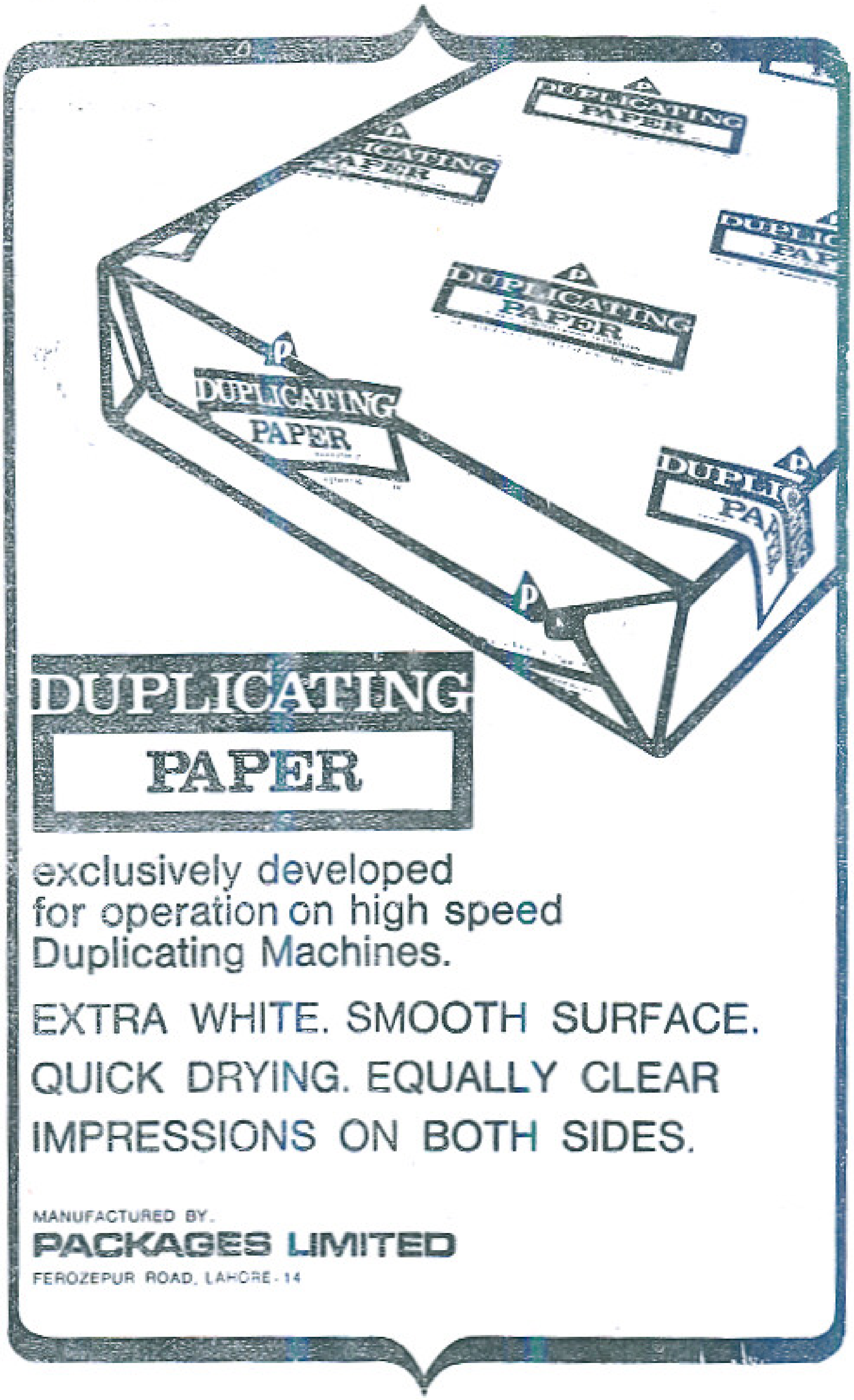
∴ Incremental cost per canal mile
=Rs. 1,702,000

(*xi*) Assuming it were possible to reduce seepage losses from 19.7 cs to 1.80 cs per canal mile then the capital cost thereof per cs reduction of seepage

$$\text{loss} = 1,702,000 \times \frac{1}{(19.7 - 1.8)}$$

$$= \frac{1,702,000}{17.9}$$

=Rs. 95,000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# TARBELA BUTTRESS STRUCTURE

*By* CH. MUHAMMAD ALI, *T.K.**

**Description of the Project**

The dam, shown in Figure 1, consists of an embankment across the 9,000 feet width of the main river valley, a group of 4 tunnels in the rock on the right abutment to provide for irrigation releases and future power, two saddle spillways cut through the rock on the left bank and discharging into a side valley, and two auxiliary dams to close the upstream end of the side valley. The Tarbela reservoir will have an ultimate gross storage capacity of 11.1 MAF & usable capacity of 9.3 MAF. The full reservoir depth will be 450 feet after completion of the project.

The main embankment dam (resting on a foundation of alluvial gravel having a maximum depth of 600.00′ will be constructed by using material excavated from the spillway channel and from the tunnels and diversion channel, additional material required will be obtained from nearby borrow areas. An impervious blanket in continuation with core of dam will cover the river bed to restrict the underflow through permeable foundations.

**Three stages of River Diversion**

The dam will be constructed in three stages in relation to Indus flows. In the first stage the river is flowing in natural channels in its existing bed. The construction activities are restricted on the right bank enclosed by a coffer dam. These include excavation of diversion channel and building of initial section of the main dam from the material excavated from diversion channel.

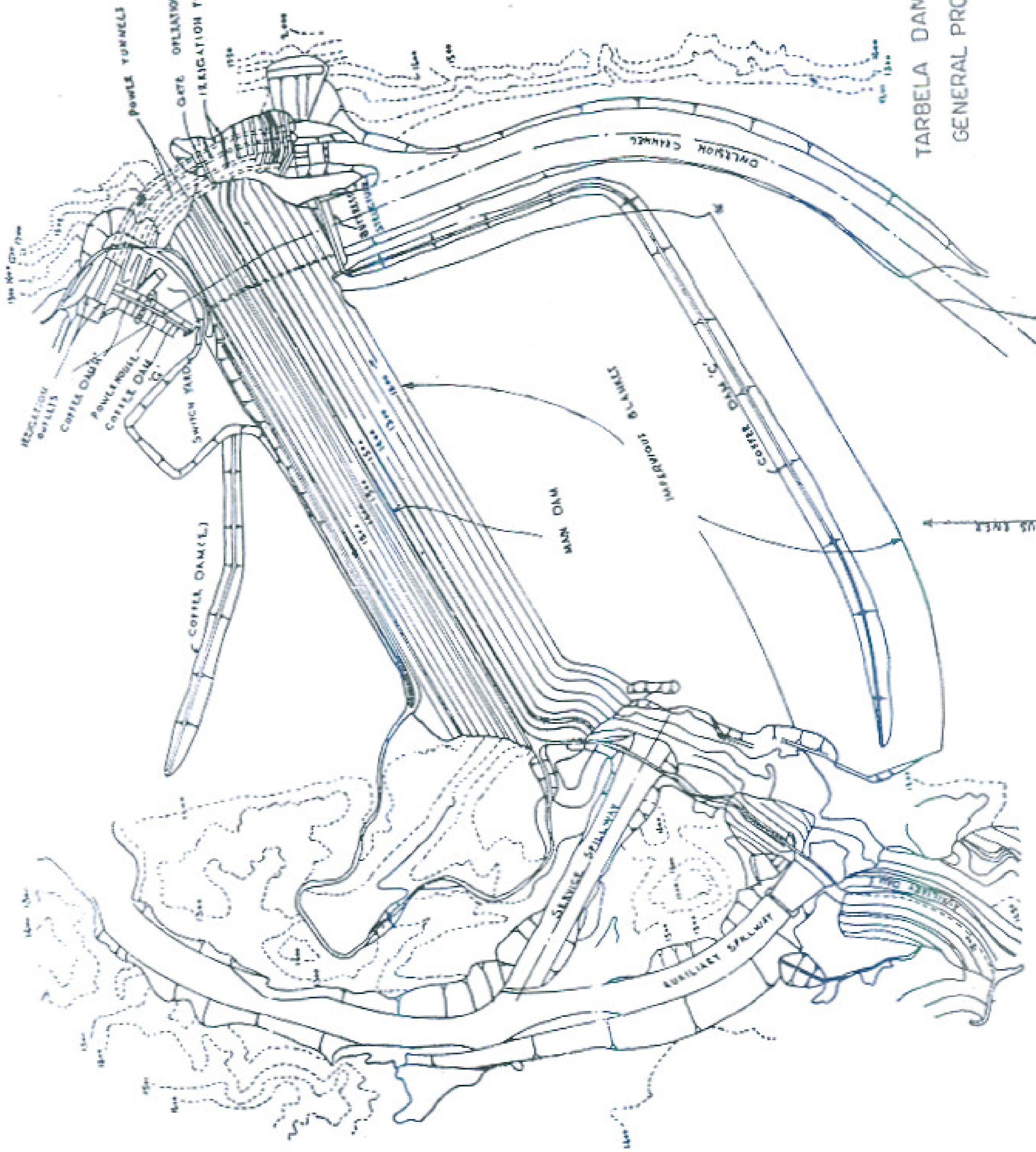
In the second state the river is flowing through the newly excavated diversion channel on the right bank while the dam is being constructed between the section completed during first stage and left bank of the valley by using material excavated from spillway channel.

In the third stage the diversion channel is closed at buttress structure and the river is flowing through the completed tunnels, while the final section of the dam on the right bank will be completed.

**Details of Stage II River Diversion**

It is estimated that four years will be required to construct the four power and irrigation tunnels on the right side of the river. During this interval the major portion of the dam in dry bed of river is scheduled for con-

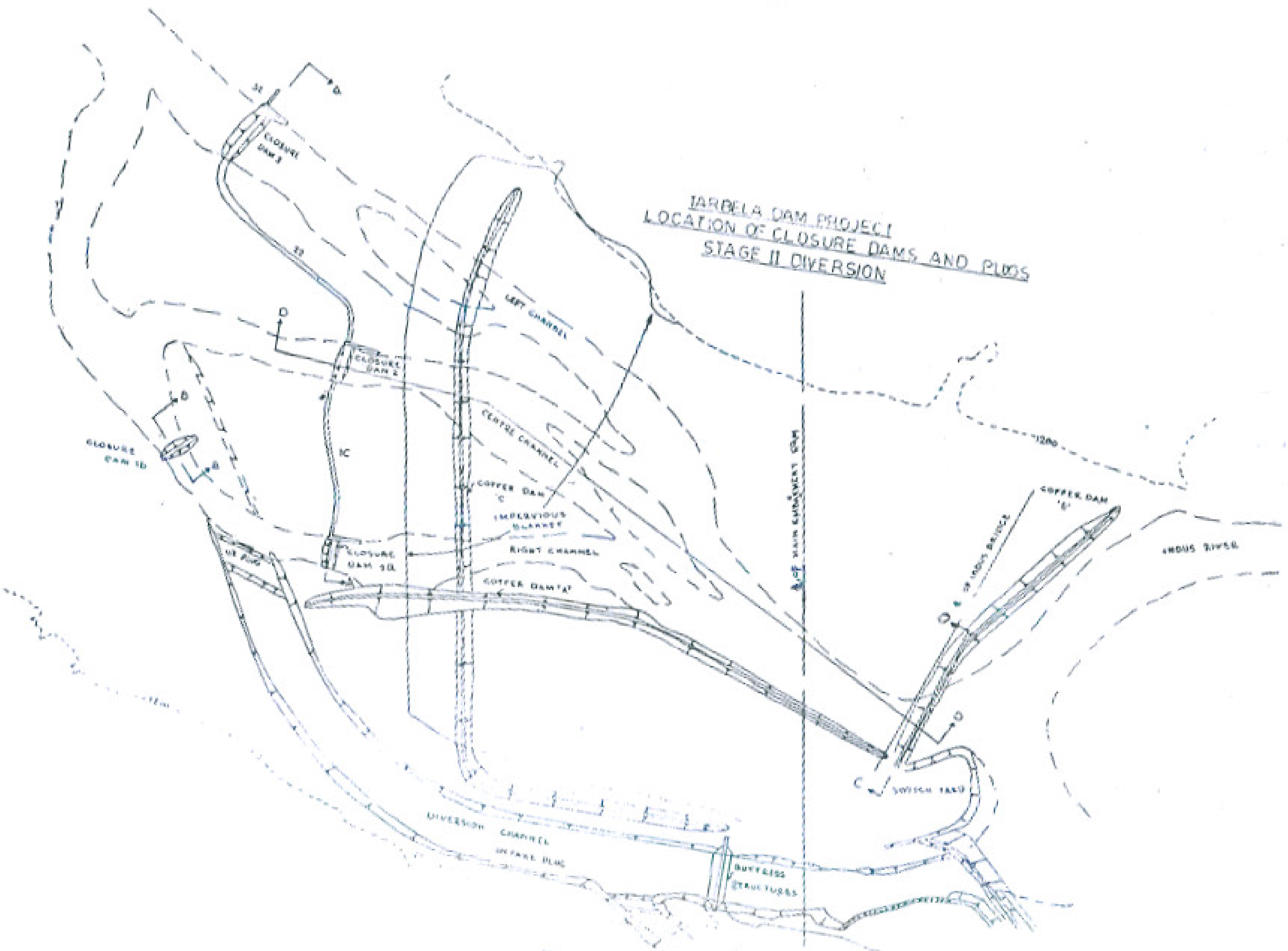
*Principal Research Officer (Hydraulics) Irrigation Research Institute, Lahore.




TARBELA DAM PROJECT
GENERAL PROJECT PLAN

Fig. 1.

Fig. 1.



JARBELA DAM PROJECT
LOCATION OF CLOSURE DAMS AND PLUGS
STAGE II DIVERSION
CLOSURE DAM 3
CLOSURE DAM 2
CLOSURE DAM 1D
LEFT CHANNEL
CENTRE CHANNEL
COPPER DAM 'C'
IMPERVIOUS BLANKET
RIGHT CHANNEL
COPPER DAM 'A'
COPPER DAM 'B'
INDUS RIVER
SWITCH YARD
DIVERSION CHANNEL
INTAKE PLUG
BUTTRESS STRUCTURES
1200


Fig. 2.

struction, and the river flow must be diverted away from the working area. This will be done through a temporary diversion channel which will be excavated on the right bank of the river as shown in Figure 2. The base width of the channel will be 650 feet and it will be approximately 10,000 feet long, skirting the upstream and downstream construction coffer-dams. A gated buttress structure located in the down stream reach of the diversion channel is shown in the figure. The gates on the buttress structure will remain open until the power and irrigation tunnels are completed.

**Buttress Structure.**

This buttress structurs is 624 feet long divided into 28 openings of 19 feet each and 27 piers each of 6 feet width. This structure from the normal bed of the diversion channel to the top of the road crossing over it, is 97 feet high and is designed to pass river discharge of 750,000 cusecs at a depth of 58 ft.

From the top elevation 1187 to elevation 1148, the buttress st ucture is provided with a concrete breast wall, elevation 1148 to elevation 1116, the arrangements have been made for fixing the stoplogs to hold the water, and the gates have been provided only for the lower-most part from elevation 1116 to elevation 1095. There will be no flow regulation at the buttress structure. At start of stage III, the plug blocking the inlet of the tunnels will be removed, the stoplogs will be lowered and the buttress gates will be closed forcing the flow to pass through the four tunnels and finally the portion of the main dam at the position of the diversion channel will be completed. The left bank of diversion channel D/S of the buttress structure is excavated in overburden to 1 on 3 slope and to protect the slope a battered concrete wall was provided at the toe of slope. The first 1800 of this wall was designed as a free standing wall (42′-52′ high) whereas the remaining 500′ wall was backfilled.

From a point about 1800 D/S of the structure a cellular coffer-dam bounding the powerhouse excavation forms the right side of the channel. Upstream of the coffer dam the right bank is excavated in rock and overburden.

The diversion channel D/S of buttress contracts to a minimum width of 575 about 2000′ D/S of buttress structure. At this point the contractor was supposed to construct a haul road bridge with girders from disassembled Indus River Bridge. The main objectives of this structure are :—

(*i*) A quick, easy and sure method of river closure to divert the river through the tunnels at the final stage of river diversion.

(*ii*) To provide a crossing on the diversion channel for construction activities on the right bank.

(*iii*) To minimise the turbulence and damp out the waves forming in the diversion channel at high stages of the river above 400,000 cusecs river discharge.

The possibility of closing the diversion channel by stone was also considered but as the river discharge at beginning of stage-III can be as high as 90,000 cusecs, the failure of closure will delay the construction and the schedule may get out of step at least by one year.

**Model Tests on the hydraulic performance of Buttress Structure.**

To study the hydraulic performance of this structure, the detailed tests were conducted on 1 : 80 natural scale model of the river and the dam area constructed at Nandipur Hydraulics Research Station. As a result of

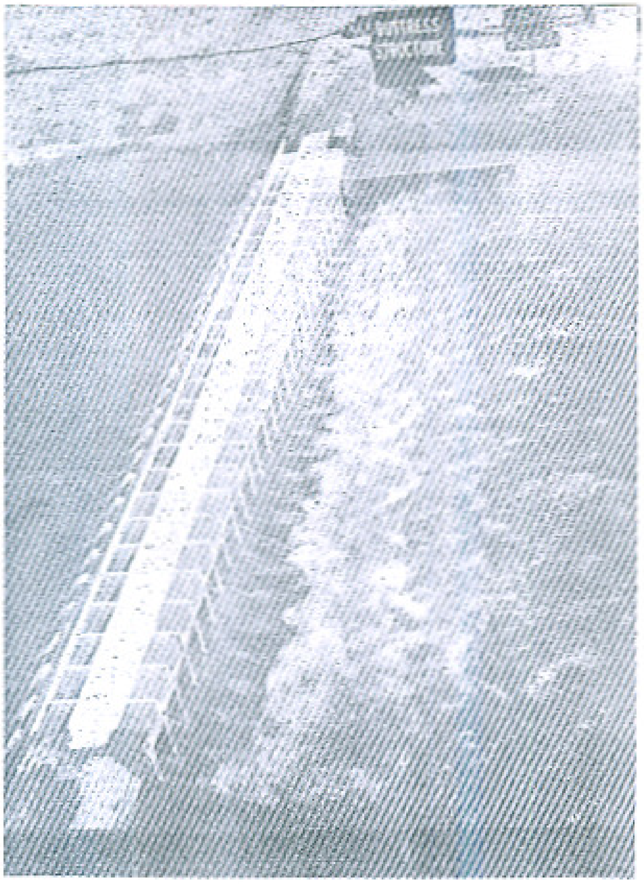


Fig. 3. Apron depressed to EL 1085 Butteress dam apron—Flow Condition Discharge 7,50,000 cfs.

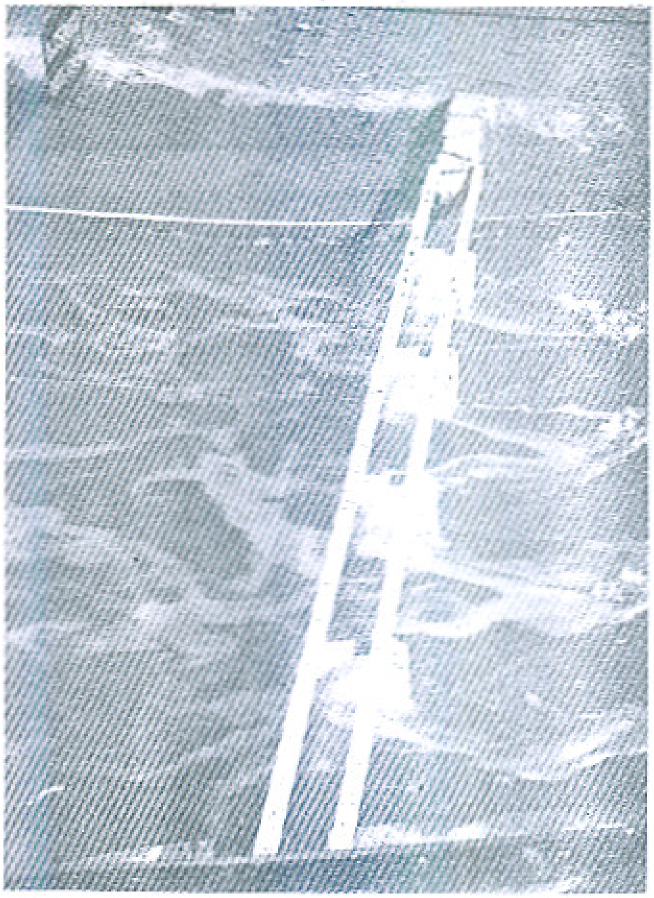


Fig. 4. Contractor's Bridge—Flow through Piers discharge 7,50,000 cfs.

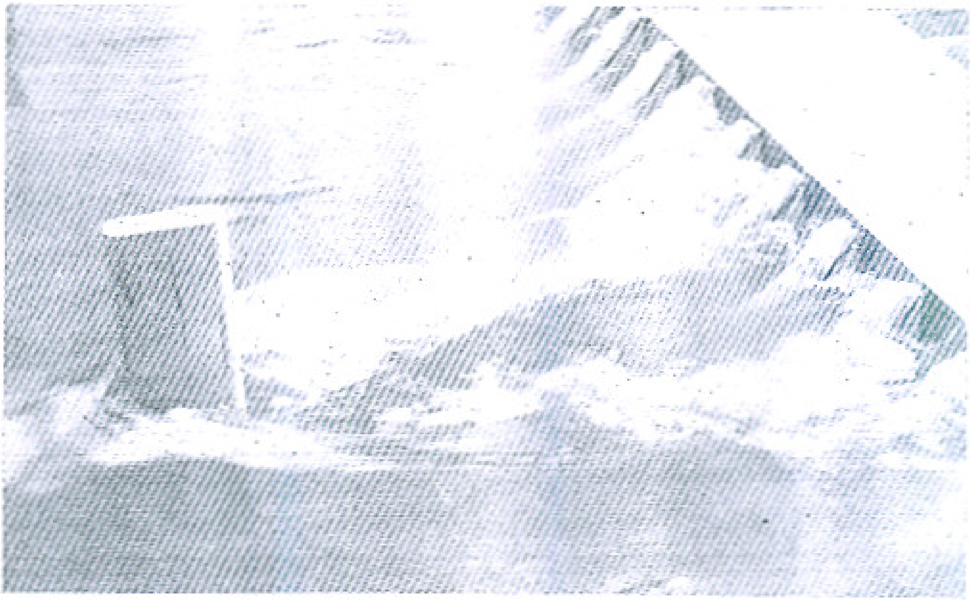


Fig. 5. Conveyor bridge—Right Pier discharge 7,50,000.

these tests, the following revisions were made in the buttress structure and the diversion channel :

1. **Apron level of Buttress Structure.** Because of right-handed curve in diversion channel approaching the buttress structure and consequent asymetric distributing of flow through buttress structure, the hydraulic jump which formed at and above river stage of 400,000 cusecs was askew being pushed beyond middle of down stream apron on right side of structure whereas it was confined entirely to down stream apron opposite left hand bays (Figure 3). The position of jump relative to the buttress structure was sensitive to tail water level. To stabilise the jump on the buttress dam apron it was finally decided to depress the apron by 5.0′ (laboratory recommended 10′ depression).

2. **Left channel walls:** The tests showed that only 150′ of this wall contiguous to buttress structure was necessary to counteract the back eddy whereas the rest of wall was not required as the velocities on the left bank without the wall were low enough to permit rip-rap protection.

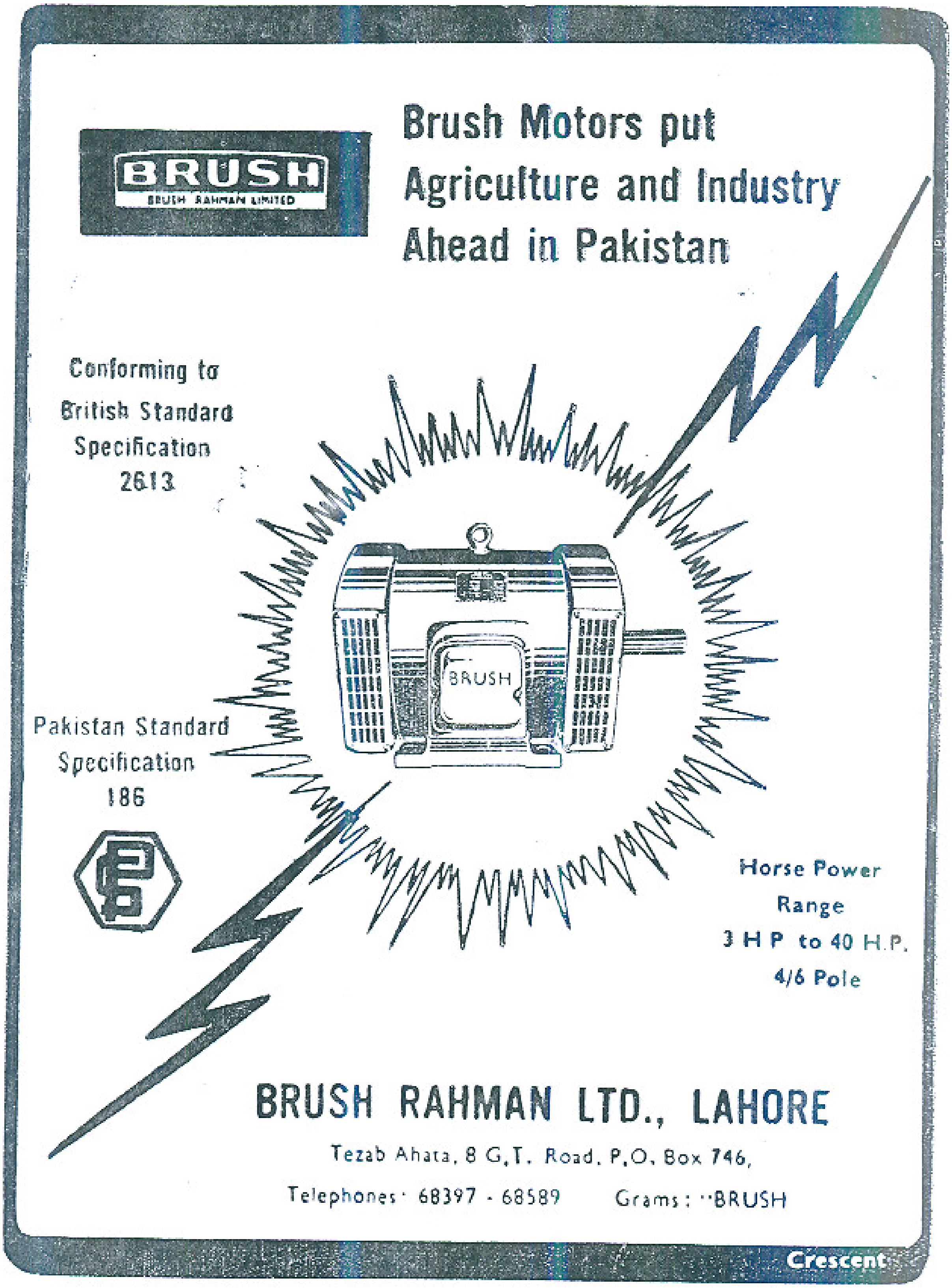
3. **Contractor's bridge :** To avoid large differential head, excessive turbulence and high vel cities (30-35 fps) generated as a result of construction and askew alignment of piers (Fig. 4) the bridge was ultimately eliminated.

4. **Junction at tunnel intake channel:** It was observed on model that tunnel intake channel if not closed off acted as a surge tank and so it was closed off at its junction with diversion channel by a suitably aligned rock plug left in place along right bank of diversion. channel.

5. **Shape of conveyer belt piers immediately upstream of the Buttress structure.** The geometary of two conveyer belt piers immediately u/s of buttress structure was streamlined to minimise eddy Fig. 5 and disturbance in the wake of piers.

6. **175′ long warped transition from right abutment of structure to right bank excavated slope :** To avoid high velocity return eddy on right down stream corner of buttress structure, a 175′ long warped transition from right abutment of structure joined to right bank excavated slope was provided in the final design.

# Buildings and Highways Section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# Study on "Hardness of Earth"

*By* CH. MOHAMMAD TAHIR[1],
G. F. ZAFAR[2] AND KAZIM HUSAIN SYED[3]

*An apparatus has been designed and manufactured in the Irrigation Research Institute to determine "Hardness of Earth" and is named* "HARDNESS MACHINE". *This machine works on the principle of twisting a standard spring at one end and shearing the soil at the other end with the help of a standard blade. A separate arrangement is improvised for calibration of the apparatus called* "HARDNESS CALIBRATOR".

## INTRODUCTION

In most of the civil engineering works huge columns of earth have to be excavated. Often contractors handling such jobs demand extra allowance on account of hardness of earth. Hitherto the only criterion applied to determine the hardness is the density of earth, and allowances are admissible if earth has a density higher than the fixed value.

A. The Institute had been receiving a number of requests from the field projects to determine dry bulk densities so that hardness allowances could be sanctioned to the excavation contractors.

B. The authors having been continuously associated with such problems could not justify this procedure to be the true criterion for deciding actual hardness of earth. The reasons are :—

(*i*) Two different soils having the same dry densities but different cohesions cannot be said to have the same category of hardness.

(*ii*) One particular soil under two different moisture conditions behaves differently towards excavation operations, the one with higher moisture will be softer although dry density remains the same (beyond plastic limit, however, the earth behaves as slush and this condition is beyond the scope of this study).

It was, therefore, considered necessary to study the problem in detail to fix up the in situ shear strength as a correct criterion whereby all influences on hardness are

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grouped together to eliminate any possible dispute about the hardness allowance.

## MEASUREMENT OF HARDNESS

When a labourer is excavating earth, he is performing two functions :—

(*i*) Forcing kassi or some other implement into the earth.

(*ii*) Shearing the earth with effort.

As such, an apparatus is needed for measurement of hardness which should measure shear strength and operate for the above conditions.

Consider a steel blade with width 'D' and height 'H' pushed into earth with a known force and turned in this position about its axis, whence the turning moment is counter-balanced by the restoring moment.

The turning moment :

$M_T$=(force applied × arm of force) .. (*i*)

The restoring moment comprises of two parts :—

(*a*) One is due to the area traversed in the form of a *circular cylinder* by the edges of the blade, and equals

$$\tau(\pi DH \times \frac{D}{2}) \text{ ft. lbs.} \qquad ..(a)$$

where $\tau$ is the unit shear resistance offered by earth *i.e.* "HARDNESS."

(*b*) The second part is due to the resistance offered by the soil to the area of the blade itself and this equals

$$2\tau\ (\frac{\pi D^2}{4} \times \frac{2}{3} \times \frac{D}{2}) \text{ ft. lbs.} \qquad (b)$$

Thus the total restoring moment becomes : (by adding *a* and *b*)

$$M_R = \tau.\pi.(DH\frac{D}{2} + \frac{2D^2}{4} \times \frac{2}{3} \times \frac{D}{2})$$

$$= \tau.\ \pi(\frac{D^2H}{2} + \frac{D^3}{6}) \qquad (ii)$$

For equilibrium conditions $M_T = M_R$ *i.e.* equations (*i*) and (*ii*) must be equal.

Thus $M_T = \tau.\pi\ (\frac{D^2H}{2} + \frac{D^3}{6})$

or

$$\tau = \frac{M_T}{\pi\frac{D^2}{2}(H + \frac{D}{3})}$$

$$= \frac{M_T}{C}$$

C=constant of the blade.

$$= \frac{\pi D^2}{2}(H + \frac{D}{3})$$

Everything on R.H.S. being known, the value of hardness can be determined.

## ORIGINAL APPARATUS

Having the above theoretical background, an apparatus shown in Fig. 1 was designed and manufactured in the Institute workshop. It comprised of :—

(*i*) Penetration blade of known dimensions (to be forced into earth by standard hammering and counting number of blows). (PART A).

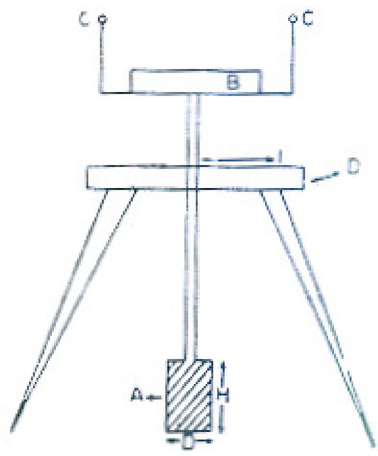


Fig. 1. Sketch Drawing of Hardness Apparatus (Original)

(*ii*) A circular spring through which turning force could be applied to the blade for shearing the earth mass. A pointer being attached with the spring to move over a graduated circular scale. (PART B)

(*iii*) Turning handle to apply the force. (PART C)

(*iv*) Angle-iron stand to support the assembly (ABC). (PART D)

## EXPERIMENTS

A platform was raised on the top of which 10 cells were constructed each having a volume of 1 cft. One type of soil was selected and compacted in each cell, firstly at a constant density but different moistures and secondly, at fixed moisture but varying densities. Hardness was determined for each case as mentioned above.

The process was repeated on other types of soils.

It was inferred from the above data that :—

1. Hardness varies directly with the dry density of soil when moisture is kept constant.
2. Hardness varies inversely with the moisture content of soil if dry density is kept constant.

## DEFECTS NOTED IN THE APPARATUS

1. The circular motion of the spring was associated with the skin friction along the sides of the spring guide.
2. Calibration of the spring in circular form was not very true.
3. Penetration process was not very precise because fraction of a blow was not measurable.

Therefore, after collecting qualitative information as given above, this apparatus was discarded and efforts towards the design of a more precise apparatus were started.

## MODIFIED APPARATUS

During the years 1970 and 71, the study was taken up more vigorously, and another apparatus was designed and manufactured in the Institute.

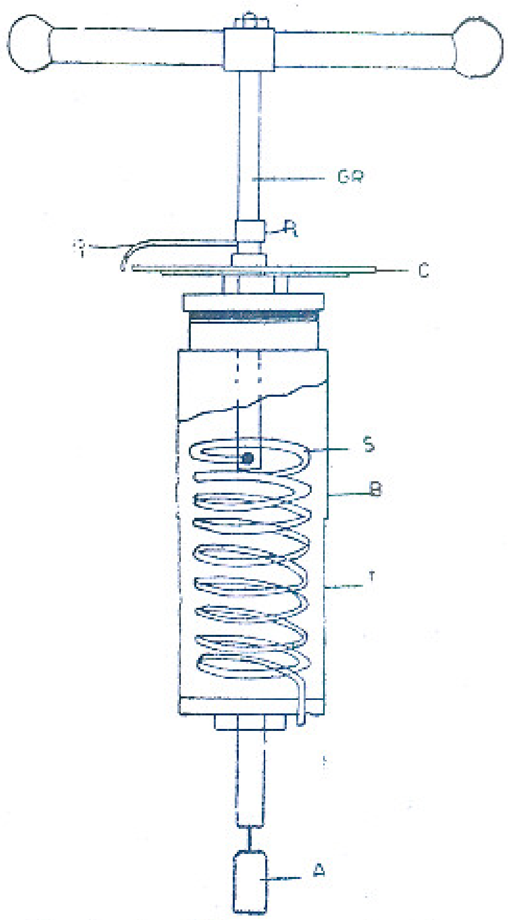


Fig. 2a. Modified Hardness Machine (Developed in I. R. I. Lahore)

This apparatus shown in Fig. No. 2-*a* and Photograph No. 2*b* is a simpler one and eliminates the defects in the previous apparatus.

It consists of :—

(*i*) 'A' is a rotating blade of dimensions (*i*) 1″×1.5″×1/32″. It is firmly attached to the tube T.

(*ii*) 'T' is a tube about 11″ long enclosing a spring 'S'.

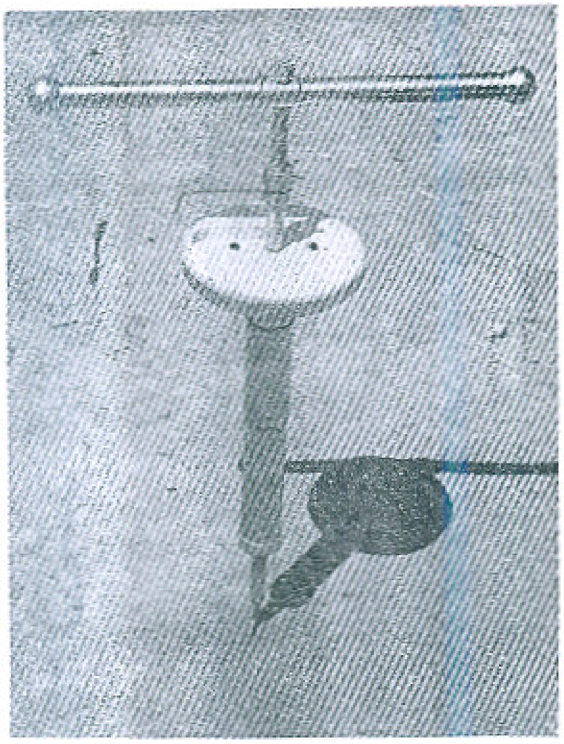

Fig. 2b. Showing the working of Modified Apparatus

(*iii*) 'B' is the portion of the tube which works as a bush during calibration.

(*iv*) 'S' is a spiral spring which undergoes vertical as well as torsional strain during working of the machine.

(*v*) 'C' is a circular scale attached to the top of the tube 'T'.

(*vi*) '$P_1$' is a pointer which moves over the circular scale and measures the shearing force of the soil.

(*vii*) 'G.R.' is a graduated rod which is connected to the spring.

(*viii*) '$P_2$' is a second pointer for measuring the penetration resistance. It slides over G.R.

(*ix*) 'H' is the handle of the machine.

**Calibrator**

Calibrator (Fig. 3) comprises of the following parts :

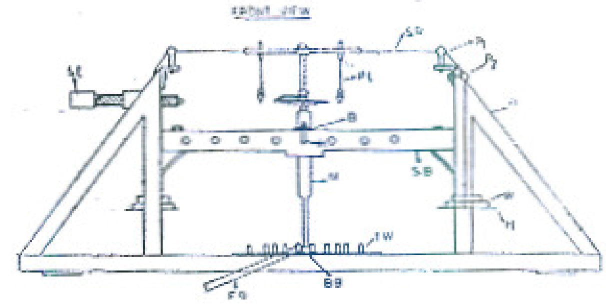


Fig. 3. Sketch Drawing of Hardness Machine Calibrator Designed and Manufactured in I. R. I. Lahore

(*i*) 'A' is the main body or structure to which the calibration arrangement has been attached.

(*ii*) 'T.W.' is a toothed wheel arrangement attached to the base of structure which could be maintained in any position simply with the help of a rod.

(*iii*) 'F.R.' is a fixing rod. The Hardness Machine blade is fixed in the jaw of this rod and rod is fixed in the toothed wheel.

(*iv*) 'M' is the hardness machine shown in position in this calibrator.

(*v*) 'S.B.' is a supporting beam.

(*vi*) 'H' is a hook provided on both the sides of the supporting beam for checking the verticality of the hardness machine.

(*vii*) 'P.L.' is a plumb line arrangement attached to the hardness machine whenever it is going to be calibrated.

(*viii*) 'B' is a second component of the bush system.

(*ix*) 'S.R.' are steel ropes which pull the handle equally on both the sides during calibration.

(*x*) 'B.B.' is a ball bearing arrangement for avoiding the frictional force produced between blade and the T.W. during calibration.

(*xi*) '$P_1$, $P_2$' are vertical and side pulleys respectively over which passes the steel rope.

(*xii*) 'H' is a hanger attached to the steel rope.

(*xiii*) 'W' are standard weights.

**Working of Hardness Machine**

This machine is quite simple to work. It is placed vertically over the site to be tested. The handle is pressed so that blade gets penetrated into the soil to a standard mark. Penetration resistance can be measured from the vertical scale. Now the handle is given a torque at a regulated speed of 0.3°/sec which is transferred to the blade through the spring. The effort is measured from the circular scale over which the pointer slides.

**Calibration**

Calibration of machine is done against standard weights. The machine is placed in position after oiling and greasing the necessary parts. The weights are gradually increased in the hanger 'H' which increases the deflection of handle. This is brought to original position by working the toothed wheel. The observations are recorded from the circular scale against the load. A calibration chart is shown in Table No. 1 and Fig. No. 4.

For a more precise calibration an average of loading and unloading is taken.

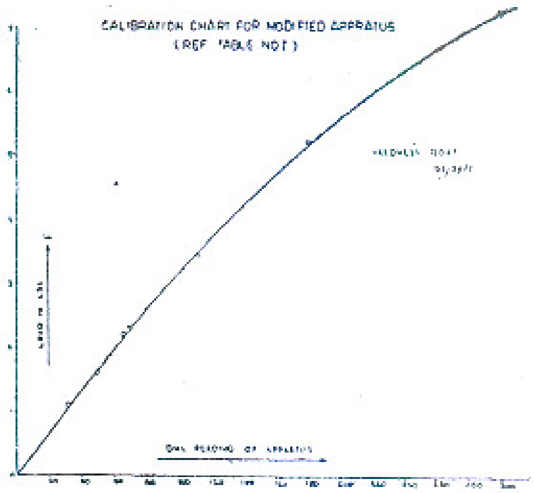

Fig. 4. Calibration Chart for Modified Apparatus (Ref. Table No. 1)

Let the total length of the handle = L ft.

= L ft.

Force acting = F lbs

Moment of force = F × L ft. lbs.

or $M_T = F \times L$

$$\text{Hardness} = \frac{M_T}{C}$$

where 'C' is a constant as already described under 1st apparatus.

$$= \frac{\pi D^2}{2}\left(H + \frac{D}{3}\right)$$

where D = width of the blade.

and H = height of the blade.

In case of modified hardness machine :

D = 1″ or 1/12′.

H = 1.5″ or 1/8′.

$$\therefore \quad C = \frac{\pi (1/12)^2}{2} \times (1/8 + 1/36)$$

$$= 1/600$$

$$T = \frac{M_T}{1/600}$$

$$= \frac{FL}{1/600}$$

In this case L=1.2 ft.

$$= \frac{1.2}{1/600} \times F$$

$$= 720\ F$$

where F= The machine reading converted into load in lbs. from the calibration chart of machine.

### Practical Experiments in Laboratory

The hardness machine was operated in the laboratory on different soils separately under different conditions of densities and moisture contents. Representative results are given in tables 2 and 3 and plotted in Figs. 5 & 6, which show the variation of hardness with dry density and moisture content of the soil respectively.

spectively. Following data was collected at site :

(*a*) Moisture content.

(*b*) Dry bulk density.

(*c*) Shearing strength.

(*d*) Penetration resistance.

Representative results are given in Table No. 4 and plotted in Fig. No. 7. All the points on this graph are found scattered and no relationship is established.

### Comparison of Penetration Resistance and Shear Strength

A comparison between shear resistance and penetration resistance curves, for all conditions, reveals that although both are linear, the former are more pronounced, having steeper slopes.

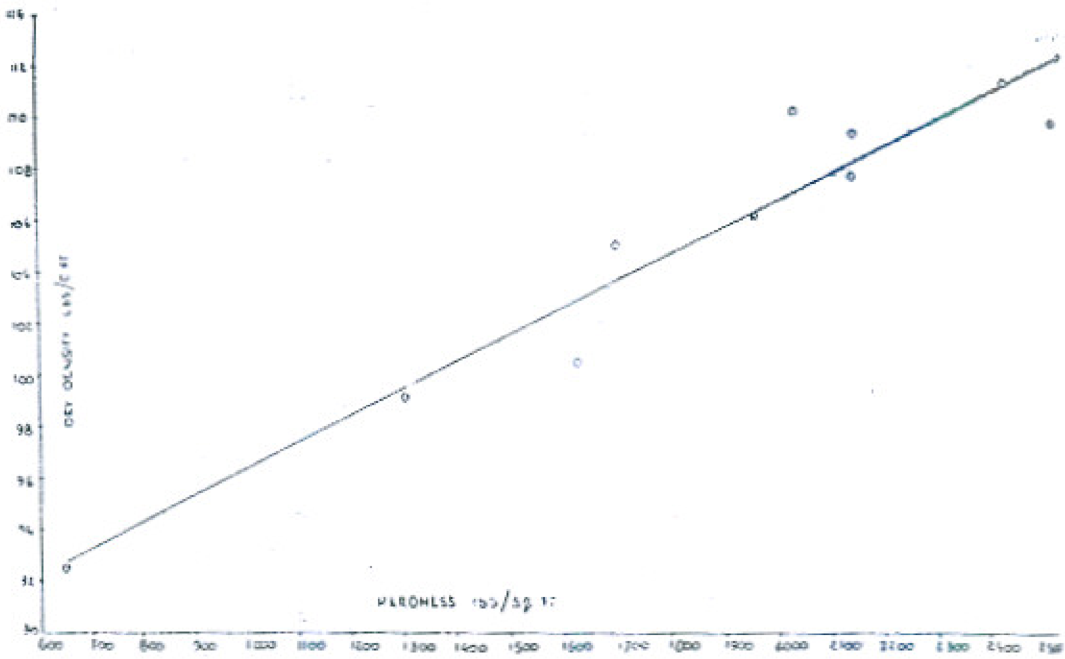

Fig. 5. Variation of Hardness with Dry Density at Fixed Moisture (7 to 8%) Lab. Tests on one Type of Soil (Sandy Silt) Ref. Table 2

### Practical Experiments in the Field

A survey was carried out along the Philloki Drain and Sangowali Drain in Gujranwala district in January, 1971 and March 1971 re-

It is, therefore, inferred that since the shear resistance results are more sensitive towards variations in density or moisture, only these should be adopted for determining the hardness.

TABLE No. 1

*Calibration Chart*

| Dial Reading | Load in lbs. |
|---|---|
| 32 | 1.1 |
| 50 | 1.6 |
| 66 | 2.2 |
| 114 | 3.3 |
| 180 | 5.2 |
| 300 | 7.2 |

TABLE No. 2

*Laboratory observations of hardness* versus *dry density at fixed moisture.*

| Type of soil | Sandy silt |
|---|---|
| sand | 14.0% |
| silt | 74.5% |
| clay | 11.5% |

| Moisture content % | Dry density lbs/cft. | Hardness machine observations | Hardness of earth lbs/sq. ft. |
|---|---|---|---|
| 7.0 to 8.0 | 92.44 | 26 | 651 |
| | 99.00 | 53 | 1301 |
| | 100.37 | 69 | 1627 |
| | 104.93 | 73 | 1699 |
| | 106.00 | 85 | 1952 |
| | 107.52 | 95 | 2133 |
| | 109.12 | 98 | 2169 |
| | 109.39 | 115 | 2530 |
| | 110.00 | 90 | 2024 |
| | 111.01 | 110 | 2422 |

TABLE No. 3

*Laboratory observations of hardness versus moisture content at fixed dry density.*

| Type of soil | Sandy silt |
|---|---|
| sand | 14.0% |
| silt | 74.5% |
| clay | 11.5% |

| Dry density lbs/cft | Moisture content % | Hardness machine observations | Hardness of earth lbs/sq. ft. |
|---|---|---|---|
| 109.0 to 111.1 | 4.5 | 101 | 2241 |
| | 5.0 | 100 | 2227 |
| | 5.5 | 115 | 2530 |
| | 7.5 | 98 | 2169 |
| | 8.1 | 90 | 2024 |
| | 12.0 | 75 | 1735 |
| | 14.8 | 50 | 1229 |
| | 16.1 | 39 | 954 |
| | 17.3 | 45 | 1085 |
| | 17.8 | 38 | 940 |
| | 22.6 | 1 | 36 |

TABLE No. 4

PHILLOKI DRAIN SITE

*Selected observations of hardness versus dry density at fixed moisture content of 5 to 6%*

| R.D. | Moisture content % | Dry density lbs/cft | Hardness machine observation | Hardness of earth lbs/sq. ft. |
|---|---|---|---|---|
| 54 | 5.0 | 93.02 | 100 | 2227 |
| 55 | 6.0 | 99.26 | 98 | 2169 |
| 56 | 6.0 | 93.02 | 83 | 1880 |
| 83 | 6.0 | 88.03 | 128 | 2747 |
| 87 | 6.0 | 93.02 | 5 | 145 |
| 88 | 6.0 | 92.40 | 20 | 506 |
| 90 | 5.2 | 103.63 | 25 | 615 |
| 98 | 5.5 | 104.88 | 40 | 976 |
| 100 | 5.0 | 104.83 | 42 | 1012 |
| 104 | 5.2 | 91.77 | 64 | 1554 |
| 105 | 5.8 | 94.80 | 64 | 1518 |
| 107 | 5.6 | 99.89 | 90 | 2024 |
| 109 | 5.8 | 96.77 | 85 | 1952 |
| 111 | 5.8 | 109.58 | 55 | 1301 |
| 112 | 5.6 | 106.13 | 75 | 1735 |
| 114 | 5.4 | 102.39 | 38 | 940 |
| 116 | 6.0 | 99.89 | 70 | 1627 |
| 117 | 5.6 | 98.64 | 100 | 2227 |
| 118 | 5.2 | 91.77 | 90 | 2024 |
| 119 | 6.0 | 92.40 | 90 | 2024 |

## Conclusions

Lab. experiments have shown that :—

(*i*) Hardness of one particular soil varies directly as the dry density when moisture remains constant.

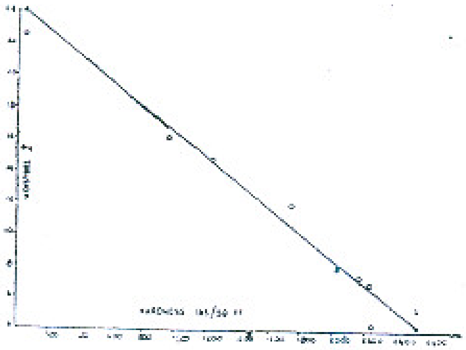

Fig. 6. Variation of Hardness with moisture in the Soil

At Fixed Dry Density (109-111) lbs/cft Lab tests on one Type of Soil (Sandy silt) Ref. Table 3

Results of field experiments have not yielded any straight line relations (Fig. 7). The reason for this deviation is that laboratory experiments were carried out on one type of soil whereas the field experiments involved different types of soils whose properties are different at different places.

It is, therefore, proved that dry density can be the criterion for "Hardness" of earth only.

(1) When a single type of soil exists all over the project.

(2) Moisture content of the entire area under study is constant.

Since these two conditions are never fulfilled in any field project, the conception of evaluating hardness on the basis of dry density is misleading.

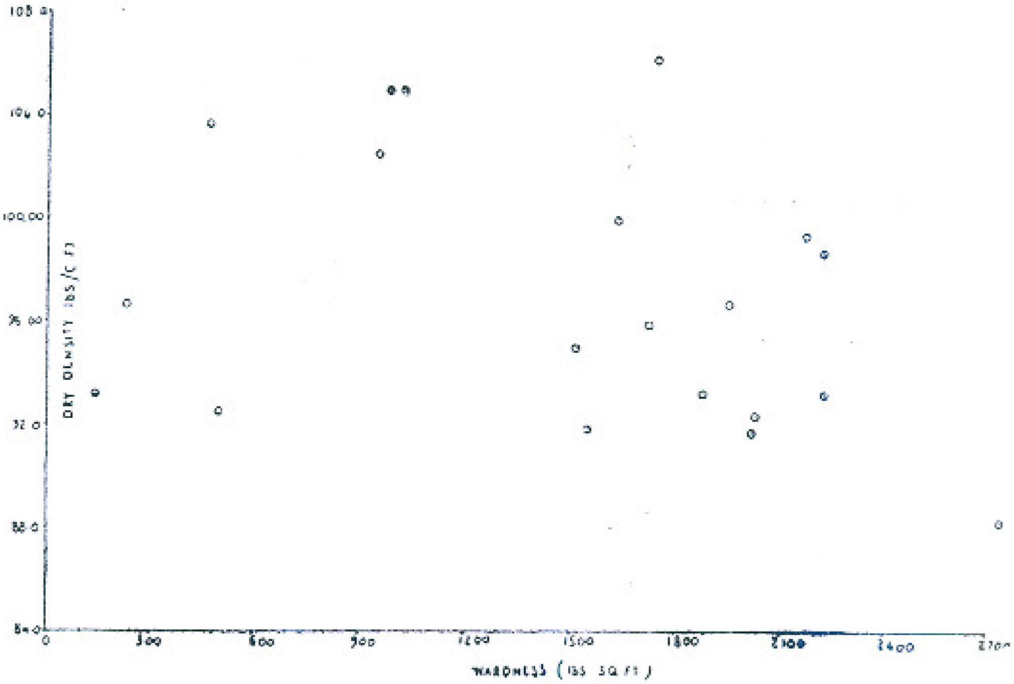

Fig. 7. Field Tests Along Philloki Drain, Variation of Hardness with Dry Density of Different Types of Soils Encountered in the Field Selected observations of Identical Moisture Contents (5 to 6%) Ref. Table. 4

(*ii*) Hardness of one particular soil varies inversely as the moisture when dry density is kept constant.

The only way to determine "Hardness" is, therefore, an *in situ* shear test which is accomplished by the apparatus discussed above and the results so obtained cover the effects of all the field conditions *viz.* moisture, density, presence of kankar and type of soil etc.

## ACKNOWLEDGEMENT

Authors are grateful to Syed Mohammad Ayoob, PSE I, Director, Irrigation Research Institute for his able guidance and Mr. Mohammad Saleem, Physicist, for his help in critical analyses of the results.

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# Pilot Plant for Expanded Clay Aggregates

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## INTRODUCTION

Natural stone aggregate is not available within easy reach in several important towns of West Pakistan *i.e.* Lahore, Sahiwal, Multan, Bahawalpur, Rahimyarkhan etc. It has to be transported from distant quarries with heavy expense which increases cost of the concrete considerably. The Building Research Station has been keen to explore avenues of replacing these aggregates with artificial ones to cut down the cost and increase thermal resistance as well. The expanded clay aggregates which have established themselves as reliable concrete aggregates in the advanced countries promised some future. But the question to be determined was whether the West Pakistani clays which are predominantly silty would bloat. The Pakistan Government decided to invite Mr. W. Kinniburgh, an expert at the Building Research Station, London who had undertaken a similar assignment in India a few years ago, to explore the possibilities and train a few scientists here in the art of assessing bloatability of clays. The laboratory tests carried out on a tube furnace indicated that most of the clays could expand or bloat to some extent and a number could bloat to a useful extent, while a few were eminently bloatable. It was also observed that many clays which were not naturally bloatable or showed marginal bloating properties, could be made to bloat eminently by the addition of about 1% of organic matter with the clay before firing.

When it became obvious that a number of clays had varying degree of bloating properties, it was necessary to fire bigger sample so as, firstly, to have sufficient material for testing and secondly, to gain experience of firing on a larger scale before commercial production. The test results of concrete have been given in a separate report which shows that the crushing strength of light weight concrete (1 : 2 : 4 mix by vol.) is more or less equivalent to the dense concrete. The design of Pilot Plant was obtained from Building Research

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Station, London and with minor adjustments carried out in collaboration with W. Kinniburgh, a final design was given to M/s. Packages Limited who offered to build the plant at their own cost and instal the same at their factory. However, an open offer was given by the management to allow free access to the Building Research Station, Lahore to use the plant any time for trials. The plant was manufactured by M/s. Packages Limited in a record time of only two months and was commissioned in March 1969 when the gas connection was given. The collaboration between research and industry at the pilot plant stage has been found to be an economical and workable proposition.

## CHOICE OF KILN

Two types of kilns are commonly used to bloat clays—(*a*) the sintering stand and (*b*) a rotary kiln. The former system is adopted where solid fuel is readily and cheaply available. In this case 6% to 10% of the fuel depending upon its calorific value, is thoroughly mixed with the clay and the mixture is fired on a travelling grate under a forced draught through series of wind or suction boxes below the grate.

If fuel is available in the gaseous form, a rotary kiln method is advisable. The kiln comprises of a revolving metal cylinder of 6 ft. to 10 ft. diameter and 40 ft. to 200 ft. long having inner lining of refractory bricks and mounted slightly off horizontal. The burners for firing are located at the lower end while raw material is fed from top which steadily travels down to the hot zone. It stays in the hot zone for a few minutes so as to complete the bloating of clay. The inclination of the kiln and its revolutions are so adjusted that the material bloats and by the time it reaches the lower (discharge) end it is not in red hot condition.

## DESIGN AND DESCRIPTION OF PILOT PLANT

Since Sui Gas is readily available at Lahore and is the cheapest fuel, Pilot Plant has been designed with rotary kiln. It is of a much smaller size than a commercial plant.

The main kiln (Fig. 1) consists of a cylindrical steel shell having a total length of 15 ft. and internal diameter of 21 in. The mouth of the cylinder expands to 29 in. towards

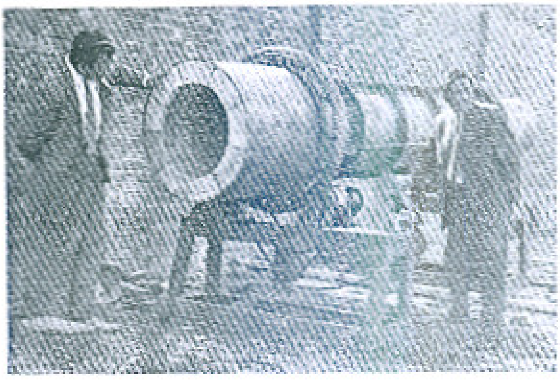

Fig. 1. Main Kiln resting on two supports. Note the refractory brick lining 4½" thick inside the Steel Shell.

discharge end for the last 4 ft. length. The cylinder is lined with 4½ in. thick refractory bricks locally available from Gujranwala. The cylindrical shell is reinforced with longitudinal and lateral stiffeners by welding T irons. The shell is made in two halves which are bolted together after placing of refractory lining. A clearance of 1" is provided in the joint of two half sections for tightening and adjustment. The kiln is supported through two cast iron semi-circular rings resting on rollers attached to two channel iron frames about 10 ft. apart. The frames are fixed in concrete floor as usual. The support on the feed end (Fig. 2 and 3) has an adjustable frame which enables the kiln to be raised or lowered to change the inclination of the kiln while the support at the discharge end merely rests on a fixed frame which has two rollers fixed in roller bearings. The rollers in the frame near discharge end are extended out and coupled with drive system consisting of gear box having reduction ratio of 50 to 1 and a 20 H. P. electric motor so as to rotate the kiln. In the initial stage, the rotation of the kiln was provided through a handle (Fig. 4) driven manually which had to be replaced by a motor.

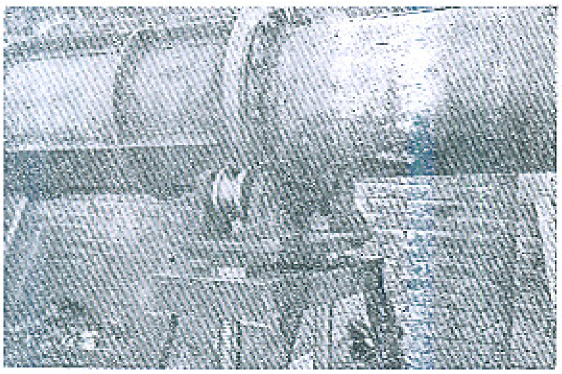

Fig. 2. Support on the feed end resting on adjustable frame.

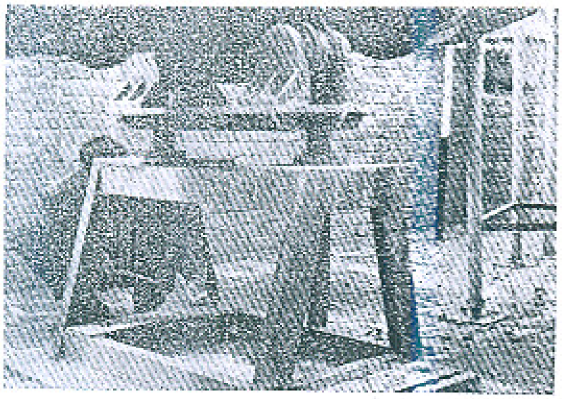

Fig. 3. The Inclination of Kiln being changed by raising the frame.

The burner is supported on a separate tripod stand which is mobile and allows movements of burner both in vertical and horizontal planes and can be clamped at any position. It is a short range burner with maximum designed gas consumption of 1 mcf/hour. It consists of 4 in. dia M.S. pipe which acts as mixing chamber for the air and gas. This gas is fed through 3/4" dia G. I. pipe having an orifice at the outlet. The quantity of gas can be controlled with the help of valve provided at inlet. The air enters at right angle to the axis of the pipe, strikes the pipe walls and forms a vortex. The vortex is further ensured by passing the air through angular fins. The vortex formation increases the mixing time and makes a homogeneous mixture. The air is provided by locally made blower coupled to the electric motor. The blower has been designed and fabricated by the Mechanical Workshop of Packages Limited.

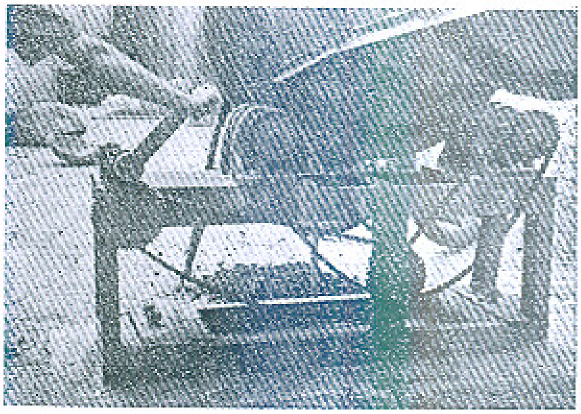

Fig. 4. Kiln being rotated manually through the hand.

The burner is placed away from the discharge end of the kiln. The length of flame between the burner and kiln is covered with an M.S. sheet cone to enclose the discharge end of the kiln on one side and mouth of the burner on the other side. It is supported on three G. I. pipe legs which rest on the ground to provide for mobility.

The exhaust system consists of a curved M.S. pipe having an internal diameter larger than the outer shell of the kiln so that it fits over the feed end of the main kiln. The exhaust pipe is supported on an independent frame and has been kept mobile so that it can be fitted to kiln when necessary. The frame for exhaust pipe is also provided with screw arrangement so that it can be raised or lowered to meet various inclinations of the kiln. The exhaust pipe is fitted with a butterfly shutter to control the flue.

The feeding system conists of a funnel welded on the exhaust pipe while the neck of the funnel projects in the exhaust and is inclined towards the mouth of the kiln so that the pallets trickle down the kiln. This arrangement allows preheating and drying of pallets by the flue gases.

The complete pilot plant is shown in Fig. 5 while the design details are given in Fig. 6.

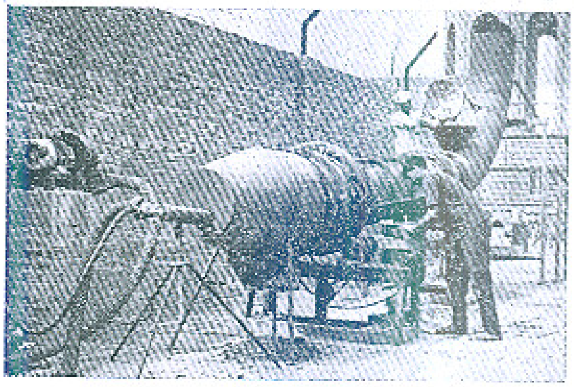

Fig. 5. Complete Pilot Plant showing curved exhaust at the far end and the burner in the foreground.

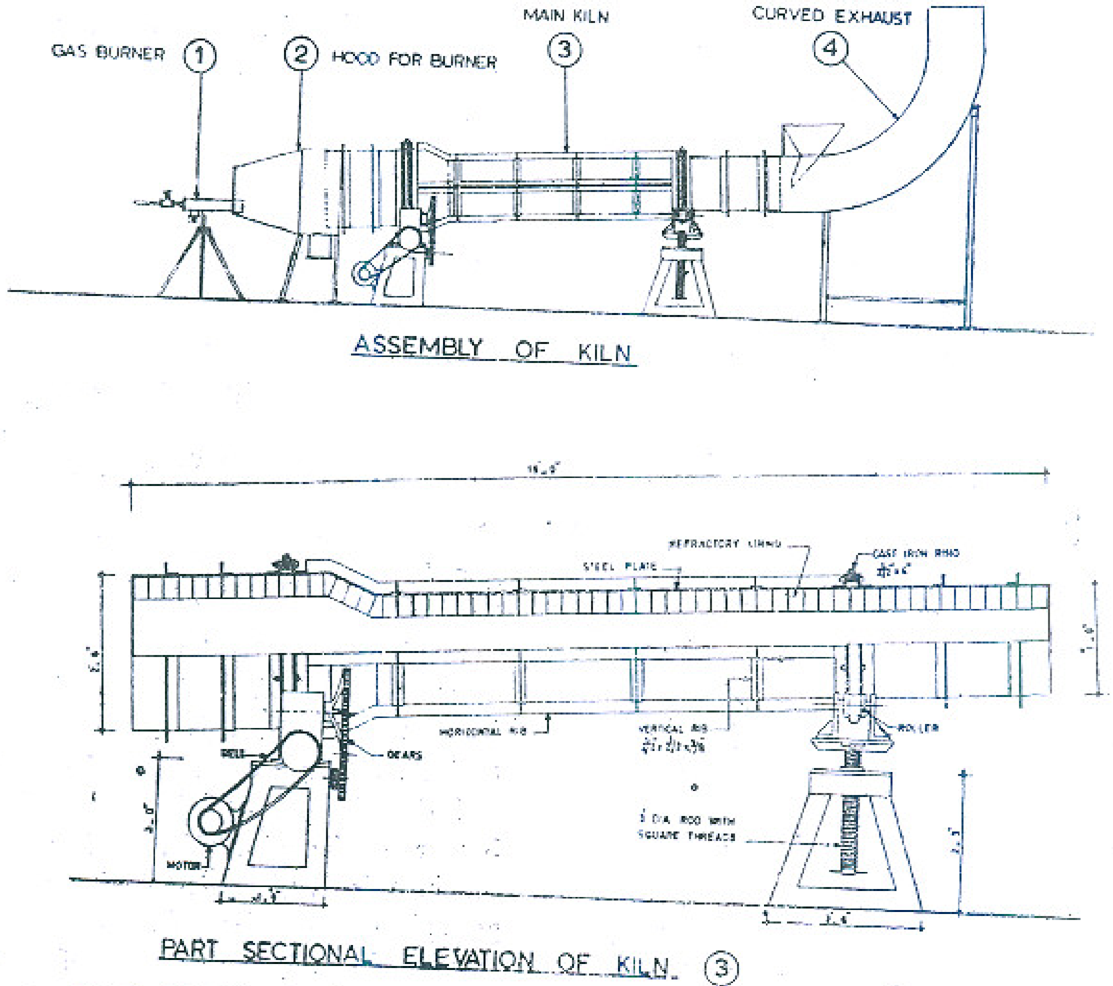


Fig. 6. Pilot Plant Rotary Kiln for Bloated Clay Aggregate, Packages Ltd., Lahore.

## RAW MATERIAL PREPARATION

The raw material comprises of sun-dried pallets made of local clay already tested for bloating in Tube Furnace of the Building Research Station, Lahore. The clay is pulverised manually and mixed with water and about 1% of organic package industrial waste. The mixture is well kneaded to form a hard puddle. The palletizing has been tried in a number of ways as follows :—

### Palletizing Machine

A palletizing machine was made comprising of a hexagonal drum $2\frac{1}{2}$ ft. long as is seen in Fig. 7. The drum is covered with fine wire gauze and consists of 6 tee iron pieces projecting in the drum. The drum is rotated manually after charging puddled clay. The rotation is continued till the pallets are almost rounded. The size of the pallets ranges from 1/16" to about 1" dia. They are then taken out by opening a shutter window in wire gauze cover.

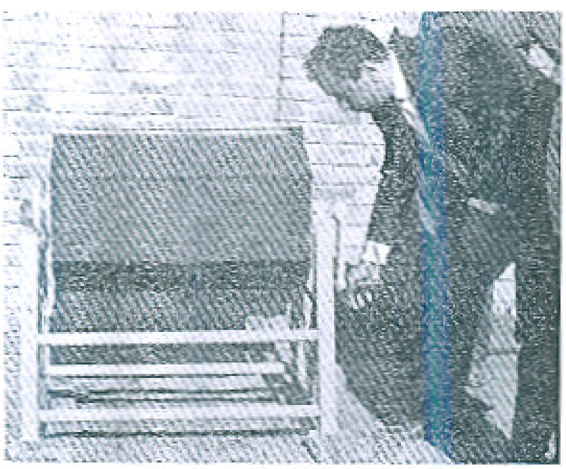

Fig. 7. Hexagonal Palletizing drum with wire gauze.

The experience of charging the above pallets in the kiln was not very happy. It was noticed that some pallets got bloated while the other did not. The product was of such a non-uniform character that it discouraged all concerned. However, it was thought that the main reason for lack of uniformity in the product was probably due to varying sizes of pallets charged and fired at the same time. This was confirmed by running a few firing trials on more or less uniform size of pallets.

### Manual Pallets

In order to tide over the above situation, the puddle is rolled into bars manually and then cut to about 1" length as is seen in Fig. 8. This gave better results but the process was experienced to be too cumbersome and slow and therefore unpracticable. The firing trials however gave much better results than the machine-made trials.

Fig. 8. Hand-rolled puddle bars being cut to sizes.

### Extrusion Machine

Lastly, a locally, made extrusion machine has been tried which screws out 4 columns of clay 1/2" × 1/2" as is seen in Fig. 9. The extruding columns are cut manually with a sharp edge to form pallets. This system has been found to be quite satisfactory.

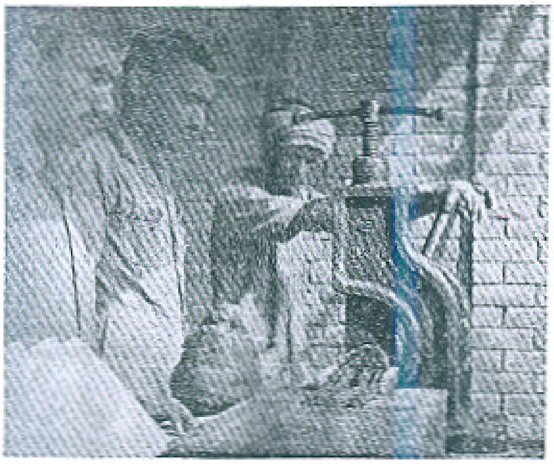

Fig. 9. Extrusion machine showing clay columns extruded manually.

## PLANT OPERATION

To start with, the burner is fired from the side hole in its conical cover and the flame is adjusted by controlling the gas, the air being at a constant pressure. Excessive gas supply will coat the aggregates with blackish tint of uburnt carbon. The kiln is rotated simultaneously and is heated till the temperature reaches about 1150°C in the sintering zone. Sun-dried clay pallets (about 1/2 cft) are poured into the hopper near the feed end of the kiln. The pallets start heating up and also gradually tumble down the inclined rotary kiln towards the sintering zone where they get bloated and are then automatically discharged out.

Retention time of the pallets in the kiln is a very important factor. If the time is more than necessary, the material gets fused causing agglomeration and if it is less, the material remains unbloated or nominally bloated. Therefore retention time required for proper bloating has to be determined by trial and error by adjusting the slope and rotation of the kiln. For the local clay tried in the pilot plant, the retention time had been about 7 minutes in the kiln with 12" inner dia and 3 minutes in the sintering zone with kiln slope maintained at 1 in 16 and about 2 rotations per minute. When the slope and rotation of the kiln are fixed, the retention time is automatically controlled.

It is essential to maintain a constant temperature in the kiln. This is done by regular supervision and by adjusting the flame of the burner and the exhaust opening because the temperature tends to fall down when new feed is poured in. Reduction in the exhaust opening helps in raising the kiln temperature and vice versa. The temperature in the kiln is measured by Optical Pyrometer. When temperature is once maintained, an experienced eye can also detect the fluctuations in kiln temperature without any instrumental aid.

When about half of the clay pallets drop into the sintering zone, another batch of (about 1/2 cft) pallets is again fed into the kiln and so on.

Temperature in the sintering zone is maximum and it decreases towards the feeding end. Since the kiln is not long enough to absorb whole of heat of the flue, lot of the heat is wasted through the exhaust. It might be interesting to mention that at temperature of about 1150°C in the sintering zone, an average temperature of 450°C had been observed at the feed end, 300°C at middle of the exhaust pipe and 260°C at the end of the exhaust pipe.

The kiln had been working for 7 to 8 hours in a day and it could never be worked round the clock due to the non-availability of staff and other facilities at night time. Therefore actual output of the kiln could not be ascertained. It has, however, been observed that the Plant could produce an average quantity of about 30 cft. (equivalent to about 3/4 ton) of the Expanded Clay Aggregate in average daily firing of 6 hours, excluding the time for its initial heating up.

## FINANCIAL ASPECT OF EXPANDED CLAY AGGREGATE

Cost of the aggregate derived from the Pilot Plant cannot have any relation with that of commercial production and will always be very high on account of the following facts :—

(*i*) It is not possible to run the Pilot Plant continuously and lot of fuel is wasted for heating the kiln each time.

(*ii*) Fuel consumption is very high due to wastage through exhaust and otherwise as the length of the kiln is not sufficient to absorb or utilize full heat.

(*iii*) The plant being an experimental one, lot of operational improvement and changes were made which increase the expense.

It is also not possible at this stage to work out accurately the commercial production cost of locally expanded clay aggregate because the cost depends upon many unknown factors such as type and size of the plant, degree of mechanism, nature of fuel, continuity in working of the plant etc. Even the producers abroad do not furnish detailed cost data due to high competition in this industry. However I.C. Bureau of Mines Information circular 8233 issued by United States Department of Interior Bureau of Mines in 1964, contains cost estimate at a Hypothetical Lightweight Aggregate Plant in the South Central States. The estimateh as been based on the data obtained by the Bureau of Mines through personal visits to various operating plants and comments of production executives. On this basis a cost analysis in Appendix 'A' has been derived for the local industry. It will be seen that the cost works out to Rs. 66% %cft. at the kiln site which compares favourably with the price of similar aggregates in America. For instance, the Consolidated Edison Limited, New York are producing expanded clay aggregates at $ 11.00 and selling at $ 18.00 per % cft. The higher cost in Pakistan is due to high cost of 'Sui' Natural gas which is available at Rs. 3.05 per mcf. for bulk consumption.

The capital cost figure assumed in the Bureau of Mines circular needs certain adjustments in Pakistan keeping in view the low labour wages. Assuming that a rotary kiln and palletizing pans can be manufactured locally, an effort has been made to give approximate cost figures of a commercial plant in Appendix 'B'. The total capital investment including 3 months running capital comes to Rs. 18,00,000/-. The selling price of expanded clay aggregates (including an annual profit of Rs. 400,000) comes to only Rs. 77 per % cft ex-works.

It is therefore evident that the production of expanded clay aggregates is a feasible and profitable proposition both for the manufacturer and the users in the areas of Lahore, Lyallpur, Sahiwal and Multan.

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## APPENDIX 'A'

### COST ANALYSIS FOR PRODUCTION OF LOCALLY EXPANDED CLAY AGGREGATE

**based on**

**Product costs at a Hypothetical Lightweight Expanded Clay or Shale Aggregate Plant in the South Central States (I). C. Bureau of Mines Circular 8233 : 1964).**

| | | |
|---|---|---|
| Total Yearly Production of Aggregates .. | 150,750 cu. yds. | .. 40,70,000 Cft. |
| Capital Cost .. | US $ 500,000 | .. Rs. 23,75,000/-. |

### COST ANALYSIS

| Sl. No. | As per I. C. CIRCULAR 8233 | | COST IN PAK Rs. | |
|---|---|---|---|---|
| | Item | Detail | Rate | Amount |
| | | | | Rs. |
| 1. | Labour : | | | |
| | (*a*) Skilled .. | 8 Nos. per day | Rs. 300/- per month | 28,800 |
| | (*b*) Unskilled .. | 16 Nos. per day | Rs. 150/- per month | 28,800 |
| 2. | Fuel-Natural Gas .. | 542,700,000 cft. | Rs. 3.05 per %o cft. | 16,55,200 |
| 3. | Utilities .. | @ $ 0.25/cu. yd. | Rs. 4.40 per % cft. | 1,79,100 |
| 4. | Maintenance & Miscellaneous Supplies .. | @ $ 0.36/cu. yd. | Rs. 6.33 per % cft. | 2,57,600 |
| 5. | Overhead .. | @ $ 0.37/cu. yd. | Rs. 6.68 per % cft. | 2,71,900 |
| 6. | Interest .. | @ 6% | 6% | 1,42,500 |
| 7. | Depreciation .. | Assuming 20 years' life of Plant | Assuming 20 years' life of Plant | 1,18,750 |
| | | | TOTAL .. | 26,82,650 |

$$\text{COST} = \frac{26{,}82{,}650}{40{,}70{,}000} \times 100 = \text{Rs. } 66 \text{ per \% cft.}$$

## APPENDIX 'B'

### ROUGH COST OF EXPANDED CLAY AGGREGATES AND CAPITAL INVESTMENT

| CAPITAL COST | | Rs. | |
|---|---|---|---|
| (*i*) Land 5 acres | .. | 1,00,000 | |
| (*ii*) Kiln 100 ft. long including lining and erection | .. | 4,00,000 | |
| (*iii*) Shed and offices | .. | 2,00,000 | |
| (*iv*) Palletizing pans | .. | 1,50,000 | |
| (*v*) Services and development | .. | 1,00,000 | |
| (*vi*) Crushing and screening | .. | 1,00,000 | |
| (*vii*) Drying and conveyor | .. | 1,50,000 | |
| Total | .. | 12,00,000 | |
| **RUNNING COST FOR 3 MONTHS** | | | |
| (*i*) Labour for 3 Shifts $30 \times 90 \times 5 \times 3$ | | 40,500 | |
| (*ii*) Excavating earth at Rs. 10 per % cft. | .. | 20,000 | |
| (*iii*) Electricity | .. | 25,000 | |
| (*iv*) Managerial | .. | 35,000 | |
| (*v*) Fuel | .. | 4,00,000 | |
| (*vi*) Sundries | .. | 25,000 | |
| (*vii*) Repairs etc. | .. | 25,000 | |
| Total | .. | 5,70,500 | say=6,00,000 |
| Running Cost for 1 year | .. | 24,00,000 | |
| Depreciation 10% | .. | 1,20,000 | |
| Interest on Capital | .. | 1,50,000 | |
| Profits | .. | 4,00,000 | |
| Grand Total | | 30,70,000 | |
| Production per year | .. | 40,00,000 cft. | |
| Selling Cost ex-Works | | Rs. 77/- per cft. | |

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